How Old is the Universe? New Results

ASTRONOMY®

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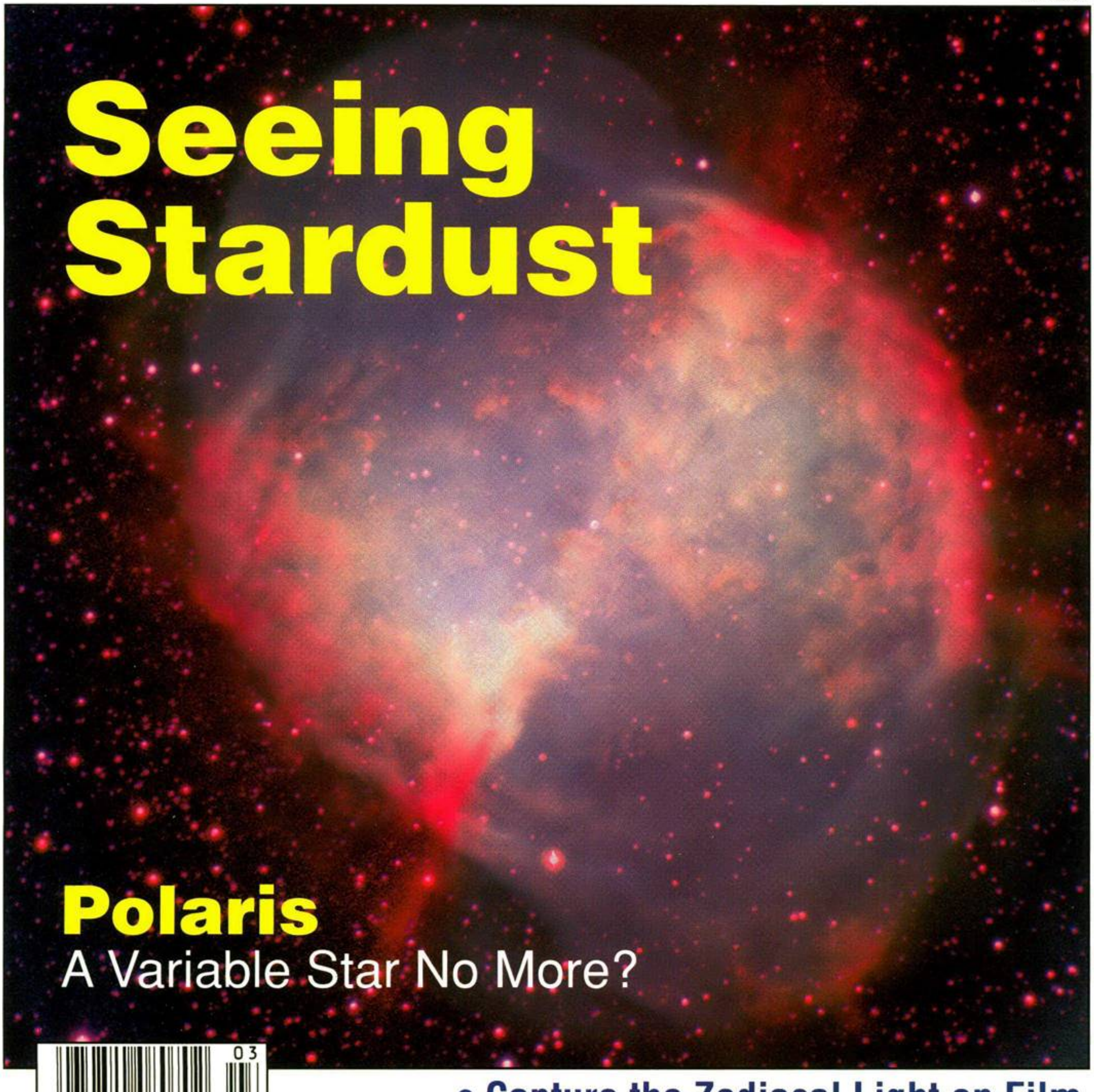
Carl Sagan:
The First New Planet



Seeing Stardust

Polaris
A Variable Star No More?

- Capture the Zodiacal Light on Film
- How to Spot the Youngest Moon

MEADE

12" LX200
10" LX200
8" LX200
MEADE LX200 EMC
Meade

Supplied complete per catalog specifications**:

8" LX200 Schmidt-Cassegrain	$2495.
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■ **All prices shown are suggested USA mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable.

■ For dealer or catalog information see the **Meade Starfinder Reflecting Telescope** ad in this issue.

LX200

SCHMIDT-CASSEGRAINS

Now with *one arc-minute* pointing accuracy and 64,350-obje onboard database as *standard-equipment!*

Meade 8", 10", and 12" LX200 models with standard-equipment High-Precision Pointing™ software now automatically GO TO any input RA and Dec, or to any object in the 64,350-object database, to a pointing precision within one arc-minute!

New Meade Version 3.30 software and high-resolution encoders, used in conjunction with the unique Meade SYNC command, now yield the most precise automatic slewing ever offered in a commercial telescope, an observatory-level of precision and *more than 5 times the precision obtainable with any competing computer-controlled telescope.* Data entry through the telescope's keypad hand controller may be made either from the onboard 64,350-object library database *(see description at right)* or by inputting the desired object's RA and Dec.

HIGH PRECISION HP POINTING

LX200's with High-Precision Pointing have the HP logo-plate affixed to the telescope's drive base.

Such precise object-acquisition, selectable during either altazimuth or equatorial operation of the LX200, has numerous important implications for the serious observer:

☐ Use the GO TO command to *find and center an object in the field of a 4mm eyepiece.*

☐ With other telescopes, acquiring even bright objects on the chip of a CCD imager is generally a chore at best, searching and slewing by trial-and-error until at last the object is positioned on the chip. The LX200's High-Precision Pointing places *every* object on *every* CCD chip *every* time.

☐ Suppose you wish to CCD-image a supernova in an 18th magnitude galaxy—a galaxy invisible *except* through the process of CCD imaging. With Meade High-Precision Pointing, the galaxy can be placed on the chip of every commercially-available CCD unit.

☐ Photographing or imaging faint objects such as the planet Pluto, or comets and asteroids near the photographic limit of the telescope, and plotting the motion of these objects night-to-night, now becomes practical, since the photograph or image may be taken *without the observer ever having seen the object visually,* but knowing that the LX200 will place the object precisely in the telescopic field.

All Meade LX200 models now include a 64,350-obj onboard database as standard equipment.

Imagine having 64,350 celestial objects at the tip of your fin 64,350 objects that you can actuate and center in the telesc field just by entering and pressing GO TO on the hand contro **More than 6 times the size of object libraries included v competing telescopes,** the Meade 64,350-object library inclu an incredible array of phenomena—virtually a lifetime of de space study, even for the advanced observer:

12,921	galaxies from the Uppsala General Catalog; the complete UGC catalog.
7,840	objects from the New General Catalog; the complete NGC catalog.
5,386	objects from the Index Catalog; the complete IC catalog.
21,815	variable stars; the complete listing from the General Catalog of Variable Stars.
15,928	stars from the Smithsonian Astrophysical Observatory (SAO) catalog of stars brighter than 7th magnitude.
351	alignment stars for the LX200 telescope.
110	Messier objects; the complete listing.
8	major planets from Mercury to Pluto.
64,359	objects, total

SPECIFICATIONS: 8", 10", and 12" LX200's—Each complete telescope incl 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain optical tube assembly EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual 5.75" worm gears, and multi-function control panel display on the drive base; ma and electric slow-motion controls on both axes; keypad handheld controller digital readout display, permanently programmable Smart Drive™, 9-speed controls on both axes (7-speed on 12"), High-Precision Pointing, and GO controller; 64,350-object onboard celestial software library; 25 ft. power cord adapter for telescope operation from 115v.AC (for field operation from any 12v. cigarette lighter plug, use the Meade #1812 Electronic DC Adapter, a 4-oz. available optionally); 8 x 50mm viewfinder with crosshairs; 1.25" diagonal prism 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 2 eyepiece; standard field tripod (8", 10") or giant field tripod (12"); foam-fitted car case; complete operating instructions.

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March 1995
Vol. 23, No. 3

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Observers with telescopes can witness Jupiter eclipsing its bright satellite Ganymede, and naked-eye viewers can look on as the Moon sweeps past Mercury, Venus, and Saturn in the morning sky. By Deborah Byrd and Jeff Kanipe.

ON THE COVER

WISPY TENDRILS of gas and dust balloon out from a dying star, thus creating the beautiful planetary known as the Dumbbell Nebula (M27). March affords the perfect chance to see the Dumbbell's more challenging cousins (see page 74). Image by Klaus Meisenheimer, Calar Alto Observatory; image processing by Axel M. Quetz.

Ivan Dyer

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NASA/JPL

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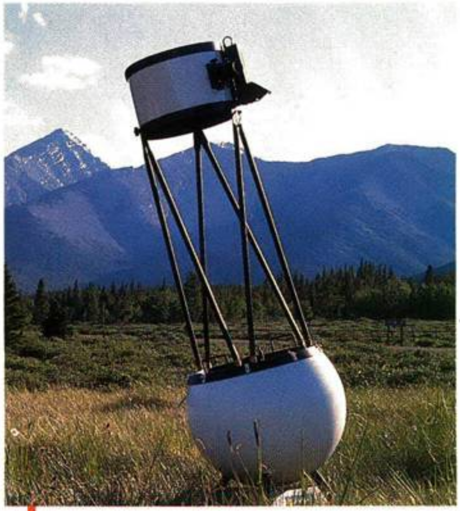

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March offers eagle-eyed observers two chances to spot the slimmest of crescent Moons. By Richard Talcott.

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This subtle, milky-white glow appears in the west on March evenings, after the last vestiges of twilight disappear. By Jeff Kanipe.

COVER 74 Challenging Planetary Nebulae

The stardust and nebulous remnants of dying stars reveal their subtle details in even a modest backyard scope. By John Franch.

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BEHIND THE SCENES

Reaching for the Elusive

It was 10 years ago that I first saw the zodiacal light and knew it. I was on Kitt Peak with a friend who was just starting an observing run, and we were standing outside one of the domes on the south end of the mountain, enjoying the last moments before twilight ended and work began.

No wind stirred over the mountaintop and the night was warm for January. The hum of machinery within the dome carried outside to us as we looked up at a calm, starlit night filled with thousands of pinpoints. I glanced to the southwest and saw first dazzling Venus and then above it, ocher-tinted Mars. Venus was so bright that when I moved my hand in front of the white-painted telescope building, I could clearly see a sharp-edged shadow.

Then I refocused my attention to look at what surrounded Venus and Mars. A cone of light stood up from the horizon, leaning southward a little. I first dismissed it as lingering twilight or the glow from some distant city. But with a jolt I realized I was completely wrong. This light had a different shape than sunset and no city lay southwest of Kitt Peak.

So *that's* the zodiacal light, I whispered to myself and smiled, hugely pleased. Once recognized, it truly was unmistakable. But how many others have seen this elusive light and failed to recognize it? If this issue had a theme, it would match the title above. Many stories this month revolve around skywatchers trying to glimpse something beyond — or maybe just barely within — one's grasp. Elusive things can pose observing challenges at all levels. Spotting an extremely young Moon or glimpsing the zodiacal light with the naked eye requires good timing, but chasing down faint planetary nebulae with a telescope calls for good handling skills.

Elusives also beckon professionals, too. The recent findings on the distance to the Virgo Cluster of galaxies (and by extension, the size of the universe) all hinge on detecting small changes in scarcely discernible stars in galaxies millions of light-years away. And William Herschel, as Carl Sagan tells in the lead feature, was hunting for faint nebulae when he stumbled across the first new planet discovered since prehistory.

Sometimes the elusive doesn't seem all that far from one's grasp. As nightfall arrives a little later each spring evening, the winter constellations are slipping away. March nights, when the Milky Way hugs the horizon, are ideal for stepping outside the solar system, indeed outside our own Milky Way. Look south tonight around 1 a.m. and you're looking into the heart of the Virgo Cluster. Its galaxies are too faint for the naked eye to reach, but if you turn your imagination loose, especially with even a modest backyard telescope, you can join astronomers as they try to lay a yardstick on the universe.

Sincerely,

Robert Burnham
Editor

LETTERS

Holy Crucifixion!

I enjoyed Joel Harris' article "Totality, Cinema, and Crucifixion" (November 1994). The article presents an admirable account of the filming of the crucifixion scene in Dino De Laurentiis' 1962 film, *Barrabas.* The actual title of the film was *Barabbas,* which reflects the correct Hebrew spelling, and means "son of the father/Rabbi" in accordance with the New Testament.

Without a doubt the scene was moving and impressive. Credit must be given to the film crew for researching the February 15, 1961 eclipse. It's unfortunate that they didn't research more deeply, however. Anyone familiar with the Bible and with eclipse phenomena knows that a solar eclipse would have been impossible during Jesus' crucifixion, at least based on New Testament accounts.

The source of the misunderstanding stems from the accounts of Matthew, Mark, and Luke, who state "from the sixth hour [noon] there was darkness over the land until the ninth hour [3 p.m.]. Most biblical analysts agree that the darkness means a spiritual darkness rather than a physical darkness.

An eclipse, after all, can't last more than seven minutes, let alone three hours. The best estimates of when the crucifixion occurred also rule out an eclipse, taking place at the time. Thus, the depiction of the eclipse in the film does nothing to promote historical or scientific accuracy. — *Lucian J. Kemble, ofm, Cochrane, Alberta*

Back to the Basics

What's this nonsense about fancy equipment? I've been watching the sky for more than 50 years with nothing fancier than a pair of binoculars. Some of my best views came from naked-eye events like meteor showers and displays of aurorae. — *Lynn Erny, Port Angeles, Washington*

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Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm each: **$87.95** (3.45)

32mm (52°); **40mm** (44°) each: **109.95** (3.79)

56mm (52°; 2") **229.95** (5.48)

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Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

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SALE!

Series 3000 Plössls Save up to 30%!

Now you can buy Meade *multi-coated* Series 3000 Plössl Eyepieces—the finest moderately-priced eyepieces ever manufactured—at never-before prices!

See complete eyepiece description elsewhere on this page.

Buy one or buy a dozen!
No minimum, no maximum!

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each **$39.95** (3.45)

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For exquisite wide-angle images at low-to-medium powers, ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8, 18, and 24.5mm are superb complements to the #140 Barlow.

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Series 4000™ #140 2x Apochromatic Barlow Lens

The most advanced Barlow Lens available for commercial telescopes; includes 3-element, air-spaced optics, multi-coated. Unmatched in image resolution, contrast and color correction. Accepts 1.25" eyepieces. Lens dia. 28mm; clear aperture 26mm.

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The very latest in eyepieces from Meade optical designers, new Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. Manufactured exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce excellent results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

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5, 6.7, 9.5, 16, 25mm each: **$57.95** (3.45) **Any 2: $52.95** each; **Any 3: $48.95** each; **Any 4 or 5: $46.95** each.

Series 3000™ Plössl 40mm

A perfect complement to the Series 3000 Plössls at left, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, multi-coated. Barrel dia. 1.25"; threaded for filters. Apparent field: 44°.

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#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

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#911B
#910B
#908B
#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

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#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (3.29)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (2.98)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (3.29)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (3.29)

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.965": $27.95 (2.98) **1.25": $29.95** (2.98)

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$39.95 (2.98)

Tele-Extenders

For Eyepiece-Projection photography with any Meade or Celestron SCT. Threads on to any eyepiece-holder. Use with T-mount for your camera.

Basic Tele-Extender: *(above)* Fixed projection power; use with eyepiece for lunar and planetary photos.

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Variable Tele-Extender: Sliding cell, with lock, permits wide range of projection magnifications with the same eyepiece.

$39.95 (2.98)

T-Adapters for SCT's

For Prime Focus photography with any Meade or Celestron SCT. Use with T-Mount for your 35mm camera.

$26.95 (2.98)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

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#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

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An improvement on the traditional Kellner design, these 3-element Modified Achromatic eyepieces give sharp, faithful, well-corrected images of the moon, planets, and deep-space at an economical price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (2.98)

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■ Prices shown are suggested USA mail-order retail prices and do not include any applicable sales taxes.

■ Suggested shipping and handling charges to the 48 states by UPS or US Mail shown in ( ) next to each price.

■ Meade accessories may be ordered from any Meade Advanced Products Dealer. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

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Orders: 800-843-4780; Info.: 818-505-8424.

CITY CAMERA, Dearborn, MI.
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FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

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10" f/4.5
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6" f/8
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At the time you order any Starfinder 6", 8", 10", 12.5", or 16" Dobsonian Telescope, you can buy **two additional Meade multi-coated Modified Achromatic MA9mm and 12mm eyepieces** ***and*** **the Meade #637 6 x 30mm coated achromatic viewfinder with metal bracket for a *total* of only $49.95! Purchased separately, the 2 additional eyepieces and viewfinder sell for $125.85!** *(Shown in photo: MA9mm, MA12mm, and standard-equipment MA25mm eyepieces, with #637 6 x 30mm viewfinder.)* Offer valid until further notice.

Starfinder Dobsonian 16

16" f/4.5
$1195.

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Includes giant #682 focuser; shown with optional 8 x 50mm viewfinder.

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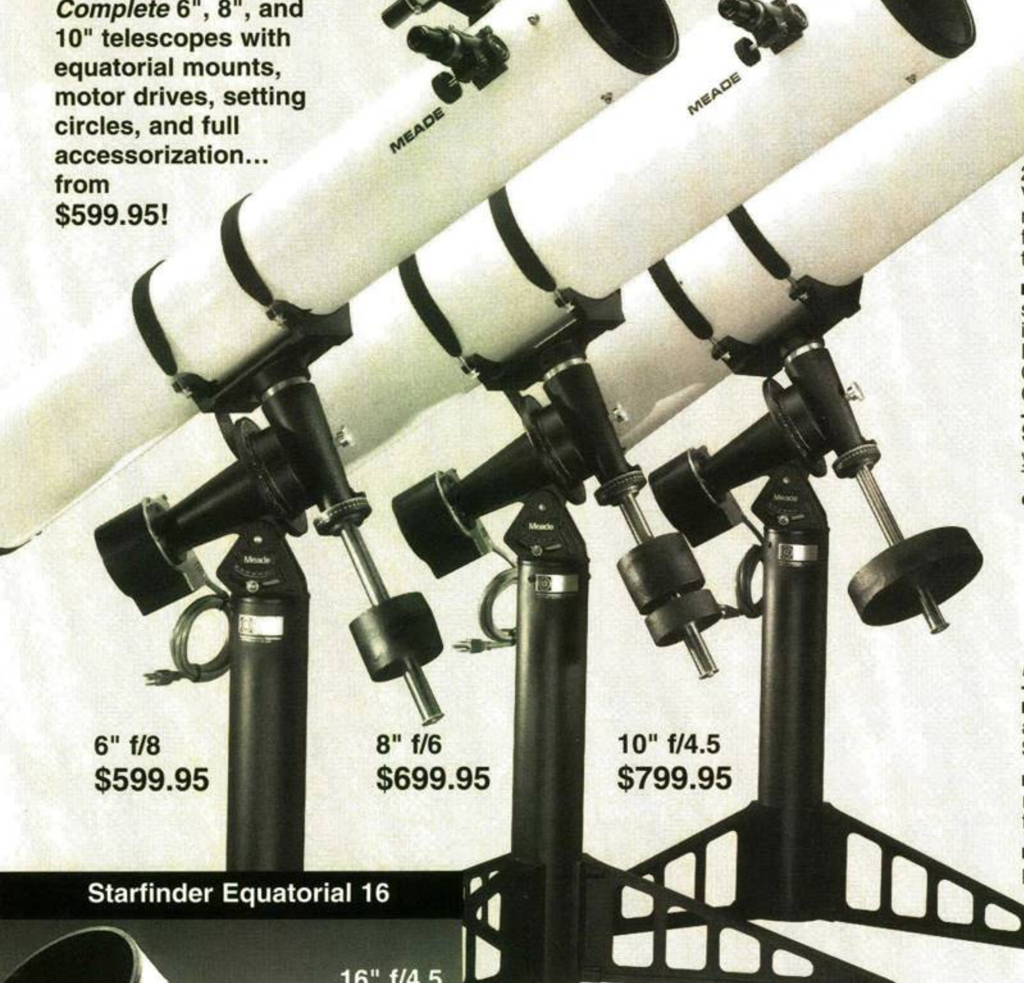

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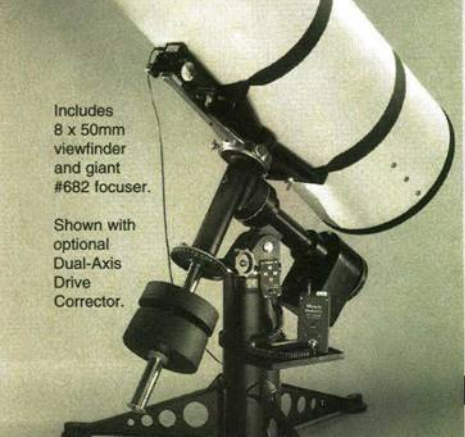

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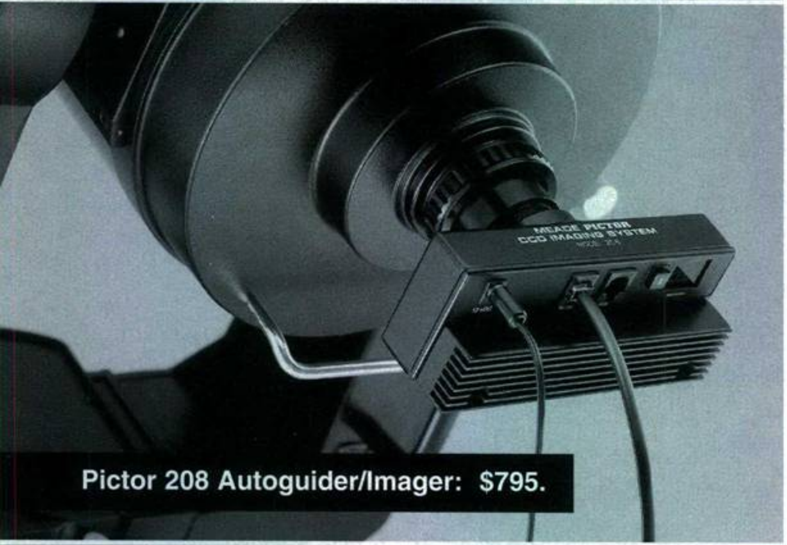
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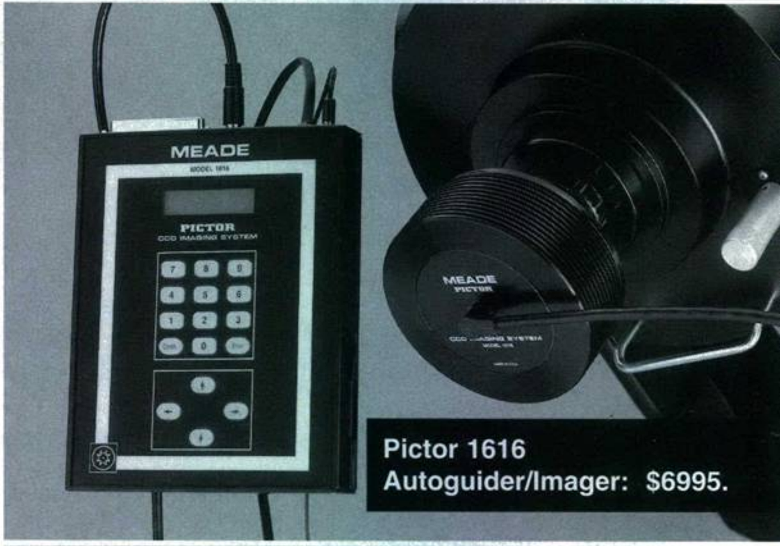
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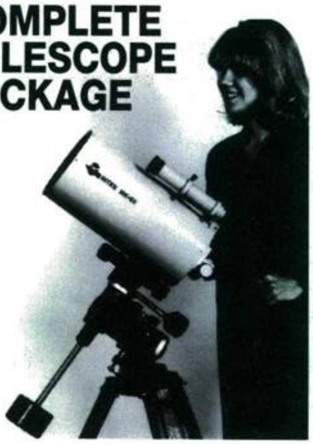

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LETTERS

I've just picked up my first copy of your magazine and have found the hornet's nest over whether or not one should buy an expensive telescope. I've been interested in astronomy and the space program for as long as I can remember, and I've never had a telescope. Owning one is by no means a prerequisite to the hobby.

I've been watching the sky for 50 years with nothing fancier than a pair of binoculars.

Lynn Erny,
Port Angeles, Washington

In addition to naked-eye gazing, I've spent many hours enjoying magazines, books, and software that simulate the night sky. I'll let those who want big telescopes fight it out among themselves. — *Stephen Clemmet, Cambridge, England*

Southern Wonders

Many thanks to Luke Dodd for his article "Under the Southern Sky, Part Two" (December 1994). Although I've never been to Australia, I feel as if I've experienced the southern sky thanks to Luke's unsurpassed photographs.

Luke's Southern Cross and Coal Sack photo is for me one of the all-time great deep-sky photographs — the colors of the stars are crisp and immediate. Luke's shot of Scorpius is also first-rate: It beats the others I've seen hands-down. Those of us who are not going to become deep-sky photographers thank the Luke Dodds and Jack Newtons of the world for sharing their images with us in the pages of your magazine. — *Joseph B. Whitebread, Jr., McLean, Virginia*

To Wrongly Go . . .

I was distressed to learn about LunaCorp's plans to send a rover to the Apollo 11 site for entertainment purposes ("To Boldly Go . . .," December 1994). Lunar landing sites, especially the manned ones, are historic sites for all humankind. While legitimate scientific investigations might somewhat disturb the sites, Joe Sixpack's remote-control driving would amount to nothing less than desecration.

While LunaCorp is at it, why don't

they send a robotic arm so that customers can scratch their names into the lunar soil or on the base of the lunar module? Something should be done to protect these historic sites. If Disney can be pushed out of Manassas, then LunaCorp should be kept away from Tranquility Base! — *Phil M. Perry, Bearsville, New York*

Traffic Tip

The next time you're pulled over by a police officer who asks you how fast you think you were going, remember that you're an amateur astronomer. Earth orbits the Sun at 66,636 miles per hour. The Sun revolves about the center of the Galaxy at 558,000 miles per hour. So you can answer, "Yes sir" (or madam), "approximately 625,000 miles per hour!"

And you thought amateur astronomy had no practical applications! — *John F. Sabulsky, Silver Spring, Maryland*

Interplanetary Isolationists?

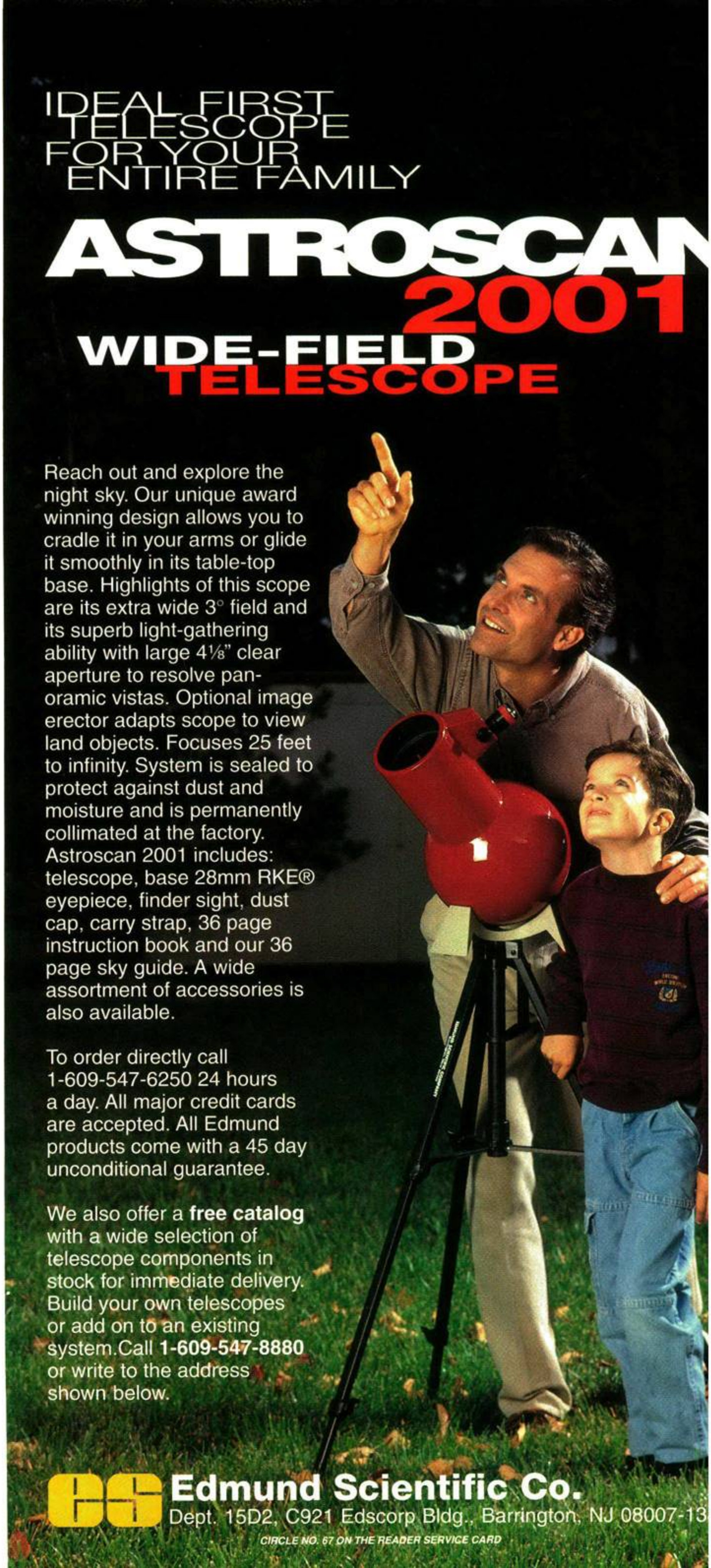
I must add to Milt Hays' letter (October 1994) regarding the loss of pioneering spirit in space exploration by the United States. We in the United Kingdom seem to have lost this spirit long ago. Sadly, the emphasis is on the advancement of an individual's life rather than greater things that would collectively benefit the society.

The trend now seems to be to cut back to funding only really cheap missions. Eventually it will mean the elimination of any space missions (while the space station creaks forward). Such an outcome would halt a major facet of the development of civilization. — *Spencer Davies, London, England*

Giving Up and Fighting Back

I enjoyed Mike Porcellino's article "Bright Lights, Deep Sky" (October 1994). But one thing he wrote bothered me. He refers to using nebula filters as "fighting back" against light pollution. If we really want to fight back, we should actually reduce the number of wasted photons streaming across the sky each night. — *Patrick L. Lilly, Colorado Springs, Colorado* □

ASTRONOMY welcomes feedback. Send your letters to ASTRONOMY Letters, 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187-1612, or on the Internet, use 72000.2704@ CompuServe.com. Letters may be edited for length and clarity.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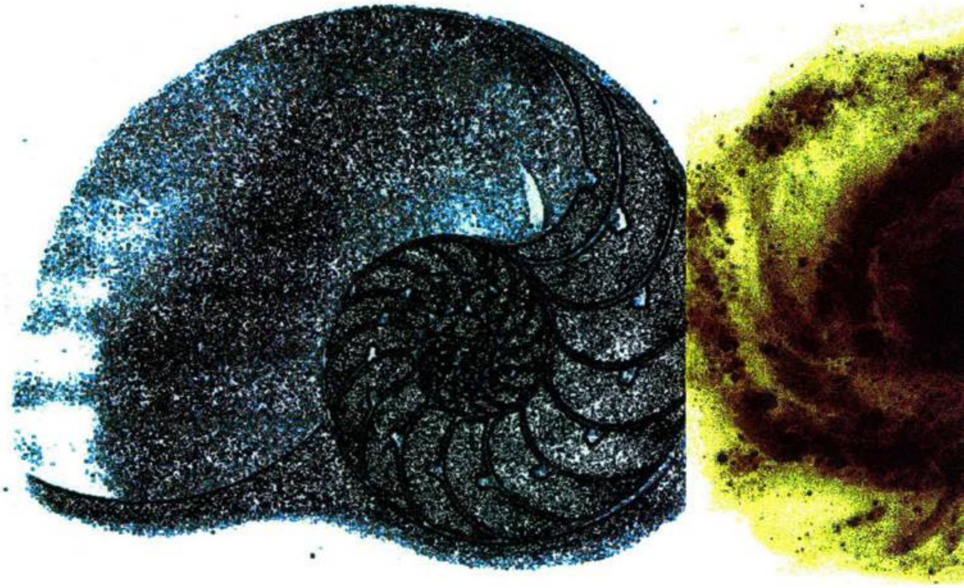
Journey into Deep Time

by Edward J. Greding, Jr.

Since childhood I have loved looking through a telescope at the faint wisps of light that reach us from distant galaxies. I've long known that the starlight from these faraway objects is old and that those galaxies appear not as they are now but as they were millions or even billions of years ago. When I look at galaxies of the spectacular Virgo Cluster, I am seeing them as they were some 50 million years ago (by comparison, dinosaurs became extinct 65 million years ago).



As a biology teacher, I am acutely aware of another universe, one that is within us, one of thought, feeling, and memory. This inner universe consists of as many interacting cells as there are stars in the Milky Way. Electrochemical impulses flick between the myriad brain cells in ways we are only beginning to understand. The power of the brain is immense, but can that brain fathom immense quantities of time? Can we comprehend the length of the journey made by the ancient light that softly glows in the eyepiece of the telescope?

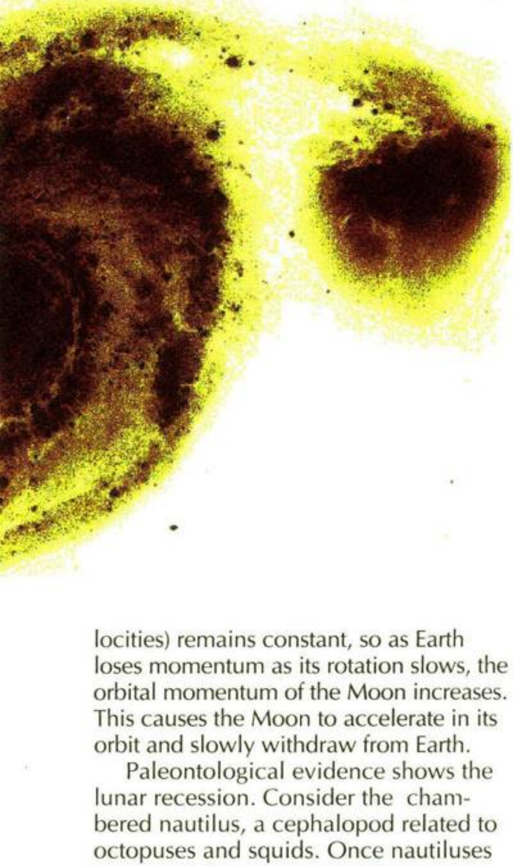
I have found a way to imagine the depths of time. It involves three seemingly unrelated phenomena: the dynamics of the Earth-Moon system, the skeletons of corals that lived 400 million years before the human species arose, and a wonderful animal called the nautilus.

In the 18th century, Edmond Halley noted discrepancies between predicted and observed positions of solar eclipses and showed that these deviations resulted from the gradual slowing of Earth's rotation. Immanuel Kant, the philosopher, correctly suggested that tidal friction causes the slowing. The Moon's gravity causes ocean tides that, as they lap against shorelines, dissipate the energy of Earth's rotation. The rate of slowing is about 0.00002 second per year; that is, every 50,000 years the day becomes one second longer.

Until the 1960s the only evidence supporting the rotational slowing came from astronomical observations. Then paleontologist John Wells found that certain long-dead corals contain in the annual rings within their fossilized skeletons a record of the passage of days and years. Within the rings are fine laminations that record daily deposits of calcium carbonate by the coral polyp within the skeleton.

Careful examination of fossil corals from previous geological periods spanning millions of years reveals that the average number of laminations within each set of rings increases as one searches further and further back into time. For example, in the Devonian period, some 370 million years ago, fossil corals contain an average of 400 laminations per ring. This indicates that the corals lived through a year of approximately 400 days, with each day only about 22 hours long. Does 0.00002 second per year make a difference? It would seem so.

This story has an additional dimension because the slowing of Earth's rotation affects the Moon. Earth and the Moon revolve around a common center of gravity. This point lies deep inside Earth because of the far greater mass of Earth. The angular momentum of the two bodies (the product of their masses and velocities) remains constant, so as Earth loses momentum as its rotation slows, the orbital momentum of the Moon increases. This causes the Moon to accelerate in its orbit and slowly withdraw from Earth.



Paleontological evidence shows the lunar recession. Consider the chambered nautilus, a cephalopod related to octopuses and squids. Once nautiluses were a mighty group, 10,000 species strong. But like so many other tribes, most have disappeared. Today only a scant five species remain. The nautilus lives within a shell and, as it grows, it secretes a new chamber into which it moves. The animal then seals off the old chamber with a septum, or wall. Between the septa of present-day nautiluses is an average of 30 fine laminations, which suggest that each lamination represents one day and the

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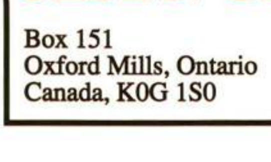

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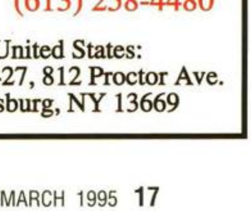

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secretion of the septa is tied to the 30-day lunar month.

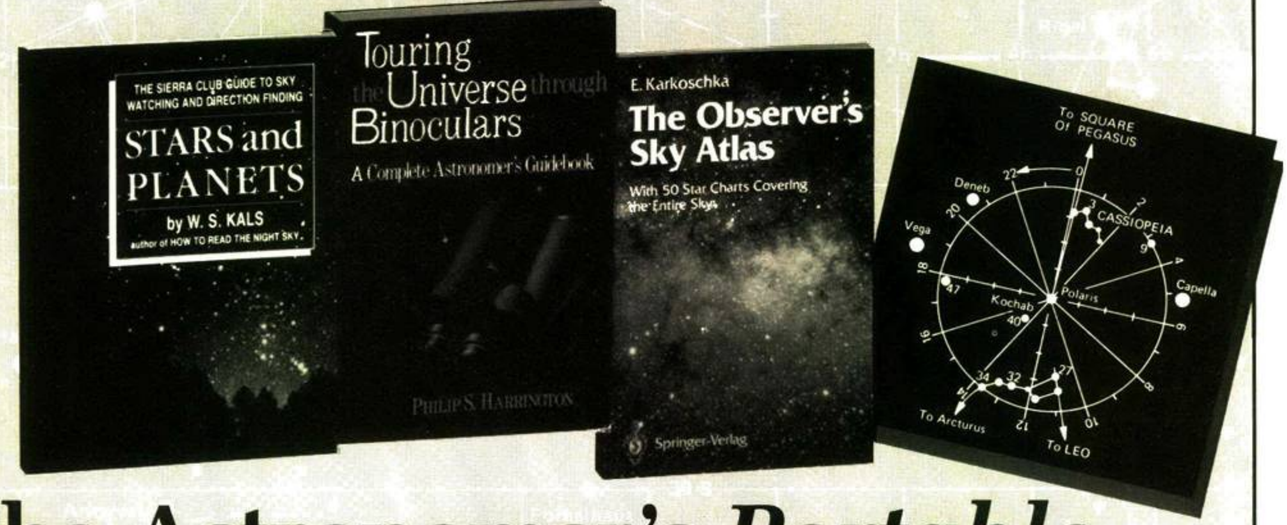
Fossil nautiloids show an almost linear decrease in the number of laminations per chamber as one examines progressively older specimens. The youngest fossil nautiloids have about 25 lamina per chamber. In the Ordovician period some 420 million years ago, each chamber contains only nine or ten laminations. The lunar cycle in the Ordovician must have been only nine or ten days.

From Kepler's laws of planetary motion, astronomers can deduce the Moon's distance in the past from its present distance, present orbital period, and past orbital period. A 10-day month means that the Ordovician nautiloids saw a gigantic Moon at a distance of about 100,000 miles — just 40 percent of its present distance. Their day would have been about 21 hours long at a rotational slowing rate of 0.00002 second per year, and each year would have had 417 days, assuming no change in Earth's orbit around the Sun.

The Grand Canyon is one place in the United States where one can peer back to the Ordovician. Recently, I stood at its rim at sunset and could see the colorful layers of rock that show so much of Earth's long history. The great chasm yawned beneath me, full of light, darkness, and shadows. I imagined I was standing at the edge of the abyss of time. I thought back 420 million years to those ancient Ordovician nautiloids, whose strange eyes had witnessed a gigantic Moon that raced through all of its phases in just ten days. Trying to comprehend the vast amount of time that had passed since those nautiloids swam in their ancient ocean made me giddy.

In the rocks of central and western Texas, I have found ancient corals and nautiloids. When I hold the fossils in my hands, they speak to me in haunting voices. For me, they carry messages from deep time: Astronomy is not only over our heads but under our feet as well. Next time you look through your telescope across the light-years to a distant galaxy, remember that seemingly insignificant 0.00002 second per year. Ponder its dramatic effect upon the Moon and the amazing record in the crust of our beautiful blue planet, unknowingly preserved by those corals and nautiloids. □

Edward Greding, Jr., is a professor of biology at Del Mar College in Corpus Christi, Texas.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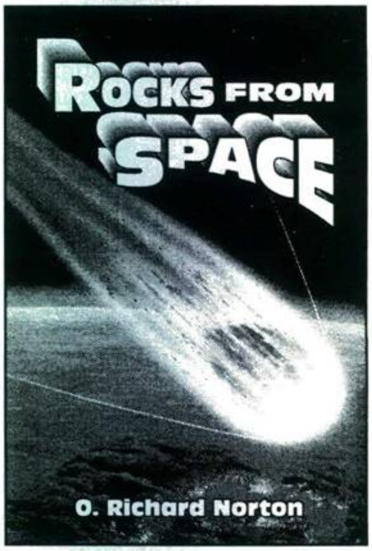

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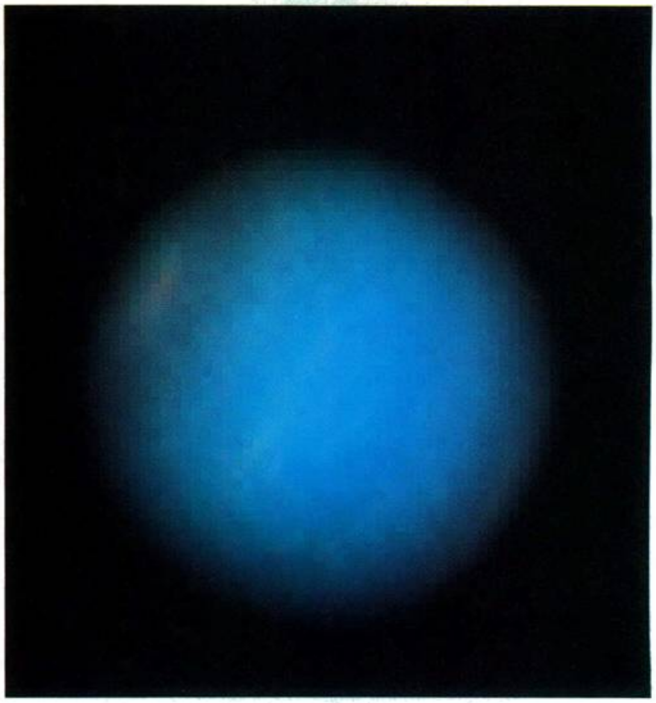
CIRCLE NO. 34 ON THE READER SERVICE CARD

Hubble Images Neptune

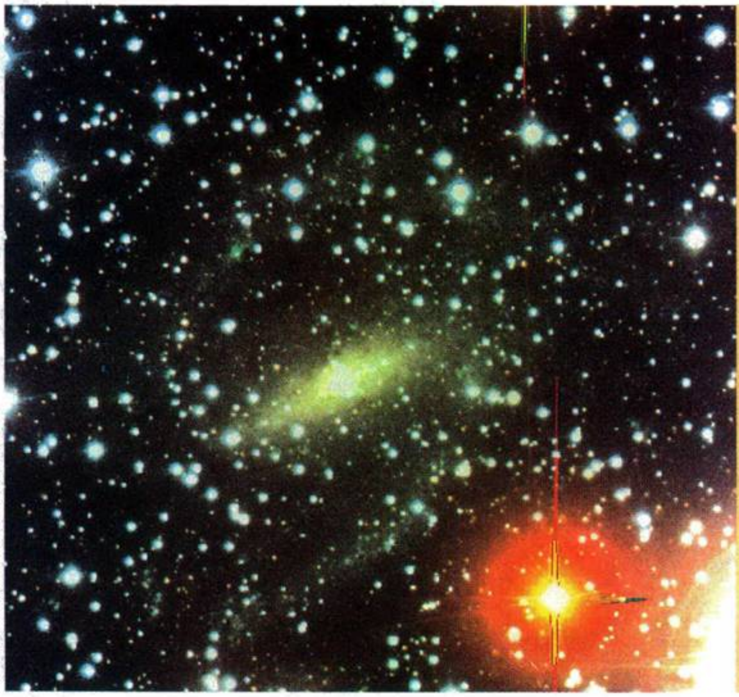
Startling new images from the Hubble Space Telescope not only show Neptune has brightened considerably over the past year but also reveal the cloud features that have caused this brightening. The new pictures show that Neptune is now at its brightest in more than 22 years. The planet appears to fade and then brighten as solar activity waxes and wanes. This relationship appeared clear until a few years ago, when it broke down. The possible connection remains puzzling to astronomers, who are continuing to monitor the distant planet for any changes.

The images were taken between October 17 and 31, 1994, by Heidi B. Hammel of the Massachusetts Institute of Technology and Wes Lockwood of Lowell Observatory. The astronomers released them and the preliminary interpretations at the Division for Planetary Sciences meeting in Bethesda, Maryland, on October 31. They find the planet's atmosphere continues to be highly active, perhaps more so than the period during which Voyager flew past Neptune in 1989. Together with earlier HST observations by David Crisp and John Trauger of the Jet Propulsion Laboratory, Hammel and Lockwood's observations, not yet completely mined, will provide new information about how Neptune's atmosphere works.



NASA/HST

BRIGHT CLOUDS GRACE NEPTUNE near its south pole and along latitudes 30° and 60° south in this Hubble Space Telescope image. Its accurate color results from combining 467-nanometer blue, 588-nm green, and 673-nm red exposures.



DOGS, S. Hughes and S. Maddox/RGO

Hidden Spiral Galaxy Found

Astronomers have discovered a galaxy only 10 million light-years away that has eluded detection until now because it is obscured by the Milky Way. The galaxy, dubbed Dwingeloo 1, is a barred spiral lying in Cassiopeia. The discovery was published in the November 3, 1994 issue of *Nature*, in a paper by the Dwingeloo Obscured Galaxy Survey team.

The Milky Way's dust and gas block the light from many such galaxies. Radio telescopes like the 25-m Dwingeloo instrument in The Netherlands can penetrate this dust, however, picking up the 21-centimeter radiation from these hidden galaxies. The radiation's long wavelength allows it to penetrate dust in the Milky Way and reach radio telescopes. On August 4, 1994, the team detected this radiation from Dwingeloo 1, visible at left in an optical photo made with the Isaac Newton telescope on La Palma in the Canary Islands.

ON THE EVENING OF August 21, 1993, Steve Bisque in GOLDEN, COLORADO established modem contact with the 24-inch telescope at the Mt. Wilson Observatory *outside Pasadena...*

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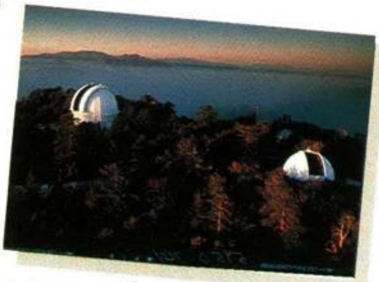

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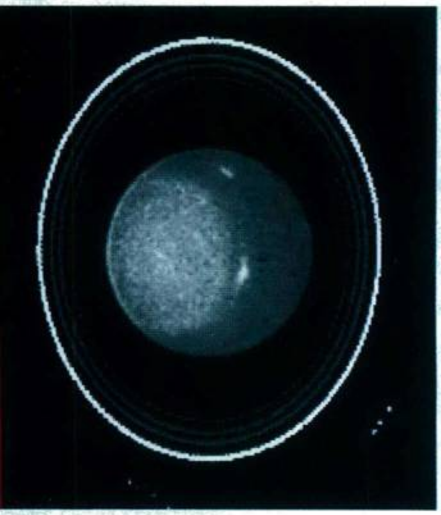
CIRCLE NO. 43 ON THE READER SERVICE CARD

Hubble Observes Uranus

For the first time since Voyager 2 flew by in 1986, astronomers have taken detailed images of the planet Uranus. On August 14, 1994, the Hubble Space Telescope's Wide Field/Planetary Camera 2 captured closeup views of the planet's rings and five inner satellites, and two high-altitude clouds in the atmosphere.

Hubble managed to resolve several of Uranus' rings, with the bright, outermost Epsilon ring appearing most prominent. A total of eleven concentric rings, each composed of dark dust, circle the planet. Three of Uranus' inner satellites show up at the bottom of the image (from left to right, they are Cressida, Juliet, and Portia). Each appears as a string of three dots because the image is a composite of three photos taken six minutes apart and shows each moon's orbital motion. In all, Hubble detected five inner satellites unseen since the Voyager flyby, which will help astronomers refine their orbits.


Kenneth Seidelmann, U.S. Naval Observatory, and NASA

RINGS, MOONS, AND CLOUDS highlight this high-resolution Hubble view of Uranus.

Finally, Hubble revealed two high-altitude clouds in the planet's southern hemisphere and a high-altitude haze hanging over the south pole. (The south pole lies toward the left of the image, tilted 35° away from our line of sight.) The clouds measure 4,300 kilometers across (bottom) and 3,100 km across (top). The clouds seem to have higher contrast than those seen by Voyager, perhaps because of the change in solar illumination. During the flyby, the Sun was over the south pole, so no variations in the Sun's position occurred during a Uranian day. Now that the planet's orbital motion has moved the pole about 35° away from the Sun, daily changes in illumination do occur.

No Massive Black Hole in Milky Way

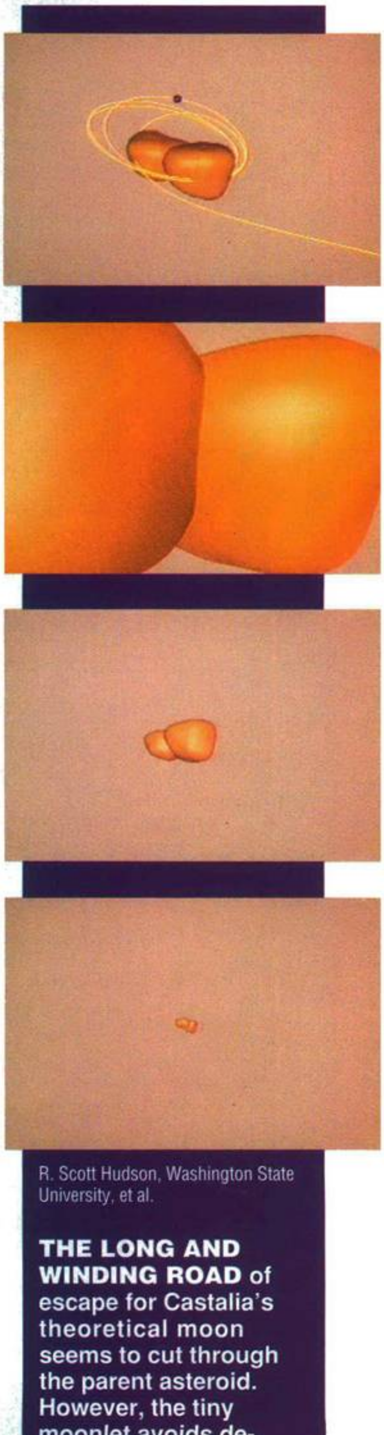
Researchers studying high-energy X-ray emission from the region of the center of the Milky Way Galaxy have concluded that no massive black hole lurks there, at least not one that is accreting mass. The finding runs counter to previous suggestions that a million solar mass black hole best explains the orbits of gas clouds and stars seen near the center.

Andrea Goldwurm of the Centre d'Etudes de Saclay in Gif-sur-Yvette, France, and her colleagues studied the region with the French telescope Sigma flying on the Russian GRANAT spacecraft. More than 1,700 hours of observations taken over three-and-a-half years enabled the team to zero in on nine sources near the center that showed emission at energies greater than 35 kiloelectron volts (keV). Of these, three stood out as having particularly "hard" spectra: in other words, they emitted at least as much energy between 75 and 150 keV as they did between 35 and 75 keV. All rank as potential black hole candidates because their spectra are similar to that of Cygnus X-1, one of the best stellar black hole candidates. But none of the three lie at the position of Sagittarius A*, the exact center of the Galaxy as determined by radio observations.

The center has an X-ray luminosity that is a factor of 10 million lower than astronomers would expect from a black hole having a million solar masses that was accreting mass. The researchers, who announced their results in the October 13, 1994 issue of *Nature*, conclude that either no massive black hole exists in the Galaxy's nucleus or for some reason, the black hole is not currently drawing in matter from its surroundings.

Castalia: The Movie

Now that asteroid 243 Ida has been found to have a tiny moon, planetary scientists are asking themselves what the dynamics are behind asteroid satellites. At the American Astronomical Society's Division for Planetary Sciences meeting held last November in Bethesda, Maryland, Daniel Scheeres and Steven Ostro (JPL/Caltech), Robert Werner (U. of Texas at Austin), and R. Scott Hudson (Washington State University at Pullman) presented computer simulations showing how a moon might orbit 4769 Castalia, an oblong, bifurcated asteroid that flew by Earth in August 1989. The team used radar data gathered by the Arecibo radio telescope in Puerto


R. Scott Hudson, Washington State University, et al.

THE LONG AND WINDING ROAD of escape for Castalia's theoretical moon seems to cut through the parent asteroid. However, the tiny moonlet avoids destruction by being in another part of its temporary orbit at the right time. The images show Castalia receding into the distance as viewed from an escaped moonlet.

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Orion nebula M 42, taken with a Zeiss APQ 130/1000. *Photo: E. Slawik*

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CIRCLE NO. 39 ON THE READER SERVICE CARD

Rico to deduce the asteroid's shape for their model. The simulation demonstrates that a variety of stable orbits are possible, some carrying a moon within meters of Castalia's surface.

What does it take to launch something from Castalia? Because Castalia spins perpendicular to its length, it's easier to hurl objects from the fast-moving ends. The escape velocity from the asteroid's center of rotation is 1.05 meters per second, and from one of its long ends 0.9 m/s.

AMATEUR NEWS

Stargazing, Connecticut Style

More than 100 observers enjoyed two nights of clear skies and a full line-up of speakers at the fourth annual Connecticut Star Party. Hosted by the Astronomical Society of New Haven, the gathering was held September 9-11, 1994, at a campground near Colebrook, Connecticut. Miles from the nearest town, the site offers some of the darkest skies in southern New England.

An observing highlight this year was the telescopic view of a satellite moving with the Earth's rotation. As background stars marched steadily westward through the eyepiece's field of view, the geosynchronous satellite's pinpoint image stayed centered. The haunting background sounds of New Age music made some people feel like they were watching a starship speed through interstellar space.

When people weren't observing, they heard talks given by professional and amateur astronomers. John Bortle reported on the amazing encounter of Comet Shoemaker-Levy 9 with Jupiter. George Chapman, a science operation specialist at the Space Telescope Science Institute in Maryland, described how his group "tells Hubble what to do every second of every day." Phil Harrington related the history of amateur astronomy, Peter Kandefer told "A Tale of Two Eclipses," and Steve Robillard and Paul Schuler III explained the rudiments of radio astronomy.

This year's star party is September 22 through 24, 1995. For more information, write CSP5, c/o Joel Marks, P. O. Box 5032, Milford, CT 06460, or call (203) 874-4816. — *Joel Marks*

Alfred Washburn

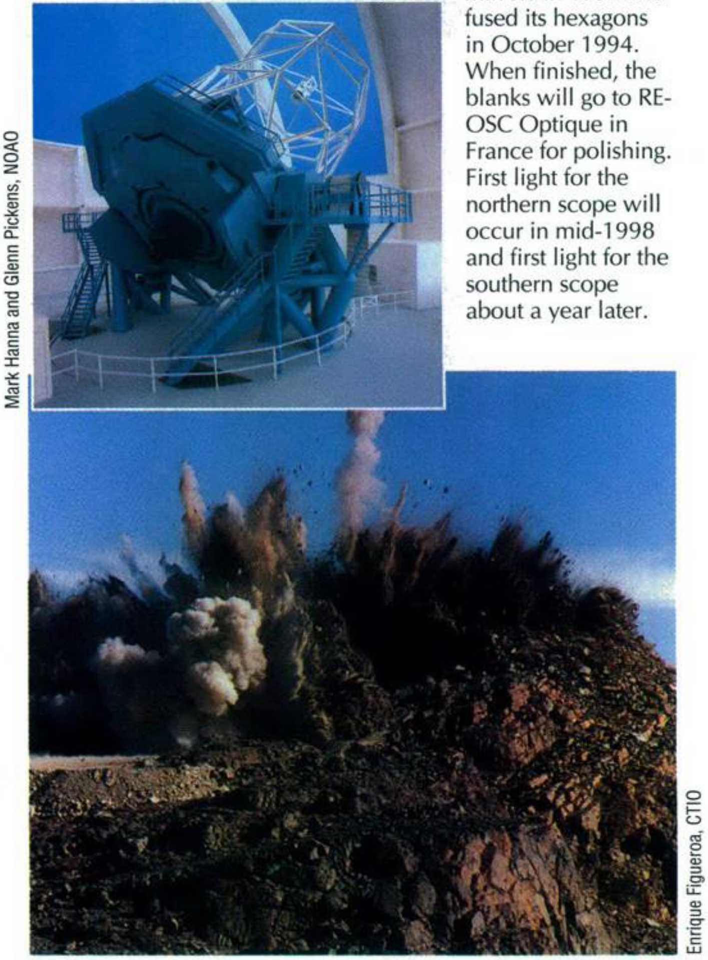
AS NIGHT FALLS over a hillside in Connecticut, campers at the fourth annual Connecticut Star Party set up for a night of visiting and observing. This year's event attracted 141 people.

Gemini Scopes Started

The two 8-meter Gemini telescopes have started to materialize on their respective mountaintops. Groundbreaking occurred October 7 on Mauna Kea in Hawaii and construction started October 22 on Cerro Pachon in Chile. Six nations have joined to build the scopes, including the United States, the United Kingdom, Canada, Chile, Argentina, and Brazil.

A round dome covers each scope. But the similarity to conventional domes ends there: Each has large vents in the sides and a forced air circulation system. The resulting air flow reduces temperature differences between the scope and outside air and provides the best possible image quality.

Corning Incorporated is fabricating the glass mirrors in its Canton, New York plant. Corning's glass engineers first make 55 hexagons that are one meter across and then fuse the hexagons in a large oven. A second turn in the oven sags the mirror to the concave shape needed to focus light. The company started the first of the two mirrors in 1992 and fused its hexagons in October 1994. When finished, the blanks will go to REOSC Optique in France for polishing. First light for the northern scope will occur in mid-1998 and first light for the southern scope about a year later.



Mark Hanna and Glenn Pickens, NOAO

Enrique Figueroa, CTIO

GEMINI STARTS WITH A BANG in Chile in June 1994, as Cerro Pachon is leveled before the start of construction of the 8-meter telescope. The model at top, built by Bob Rice of Tucson, Arizona, shows how the altazimuth scope will turn in its novel dome with vented sides.

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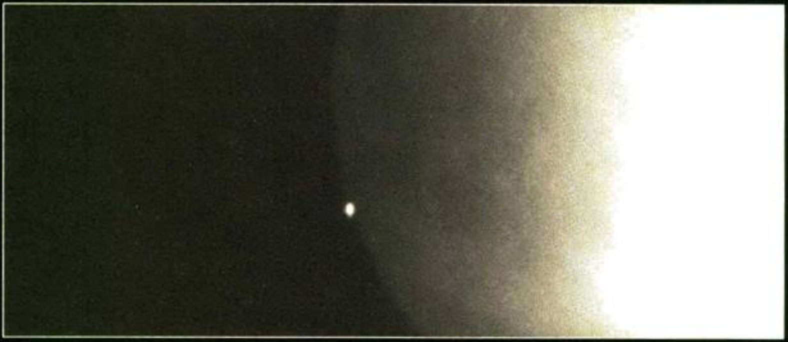

Occultation of the star Nu Aqr by the dark edge of the six day old moon. Eleven second ST-4X CCD image taken at the prime focus of a Celestron 8 inch, f/1.5 pure Schmidt camera with a f.o.v. of approximately 30 arcmin, or 10 arcsec per pixel. Courtesy William Liller, Vine del Mar, Chile.

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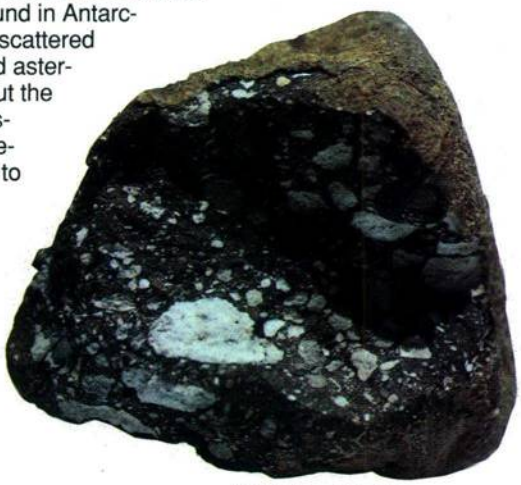
Moon Rocks Get Around

There might be a little bit of the Moon on planets and asteroids in the inner solar system, according to astronomers at Cornell University. Brett Gladman, Joseph Burns, and Pascal Lee shared this finding at last November's meeting of the American Astronomical Society's Division for Planetary Sciences. Using a computer model that subjects the Moon to a theoretical barrage, they found that 80 to 90 percent of the material blasted from the Moon goes into orbit around the Sun. Depending upon how fast it was ejected, between a quarter and a half of that material returns to Earth and Moon within 10 million years. Ejecta that escapes the Moon but goes into orbit around Earth is swept up by our planet within a few decades after the lunar impacts.

Remaining Sun-orbiting pieces have their motions changed because of close encounters with Earth. After several hundred thousand years they cross the orbits of terrestrial planets and in a few million years are evenly distributed throughout the inner solar system. In the astronomers' model, Moon material winds up on Venus and Mars and passes through areas frequented by near-Earth asteroids. This raises the possibility that pieces of the Moon are hitching rides on such notable asteroids as 4769 Castalia, 1620 Geographos, and 4179 Toutatis.

PIECES OF THE MOON, such as this one found in Antarctica, might be scattered on planets and asteroids throughout the inner solar system. This meteorite is similar to samples brought back from lunar highlands by the Apollo astronauts.



NASA photo S82-35865

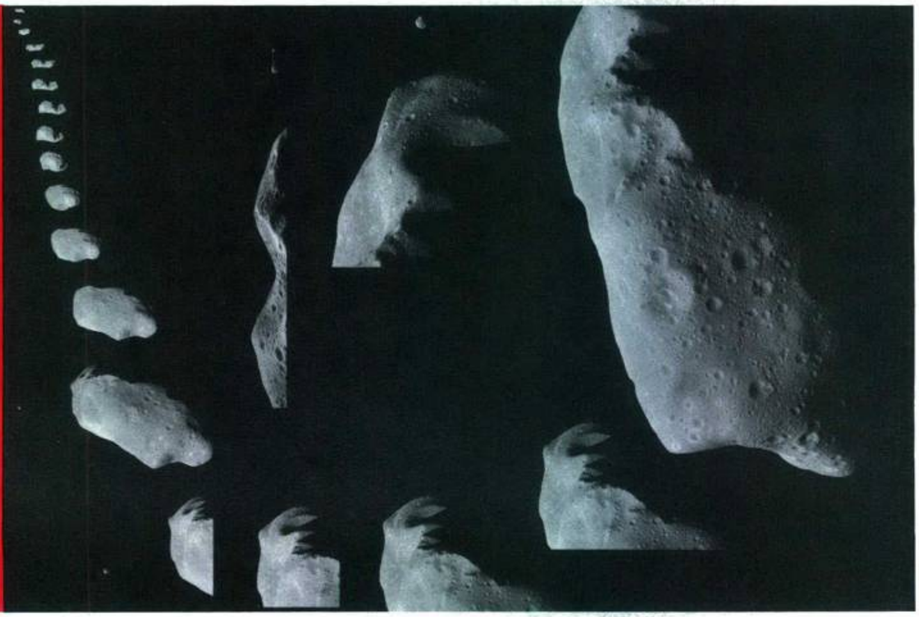
Chiron's Atmosphere Resolved

Astronomers have confirmed earlier ideas that the comet 2060 Chiron has an atmosphere of dust. Karen Meech of the Institute for Astronomy in Hawaii, Marc Buie of Lowell Observatory in Arizona, and Michael Belton of the National Optical Astronomy Observatories in Arizona imaged the comet in February and March 1993 using the Planetary Camera on Hubble. The team reported their analysis of the images at the American Astronomical Society's Division of Planetary Science meeting held in November 1994.

The team finds a change in the brightness of Chiron's coma (the diffuse cloud of gas and dust surrounding a comet) at a radius of about 1,200 kilometers from the nucleus. They interpret this change as a boundary between dust gravitationally bound to the comet and smaller dust escaping from the comet.

These observations confirm a model of the dust originally proposed by Meech and Belton in 1990. In their model, the dust particles form when carbon monoxide and other icy materials change into a gas. The newly formed gases push dust off Chiron's surface. Including ground-based estimates of the dust particle size, the model predicts that the comet has a density less than half that of water.

IDA GROWS FROM A TINY DOT to a whole new world in this series of photos taken by Galileo during its flyby of the asteroid on August 28, 1993. The first image was taken when the spacecraft was 144,000 miles from 243 Ida, about 5 hours 23 minutes before closest approach. As Ida gets larger, its 4.6-hour rotational period becomes more noticeable. By the time the 34-mile-long asteroid starts to fill Galileo's camera frame, another dot becomes visible: Ida's tiny moon Dactyl. By scrutinizing these frames for Dactyl's motion around Ida, scientists calculated Ida's density to be less than three grams per cubic centimeter, about three times the density of water.



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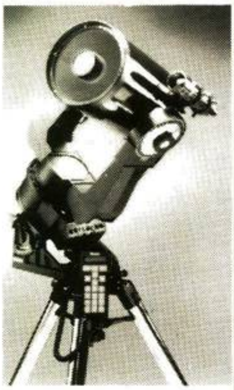

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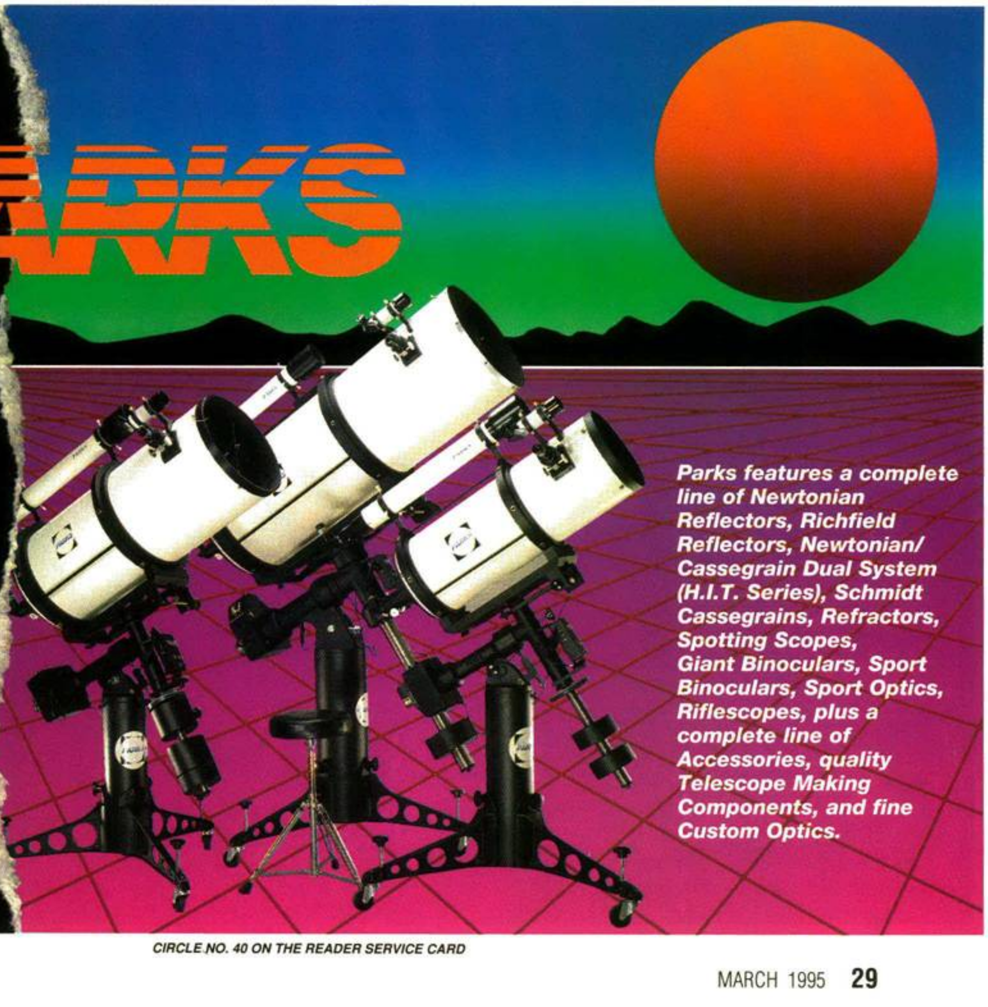

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Sure Bet for a Black Hole

Astronomers first suspected in 1989 that the binary star system called V404 Cygni contained a black hole. Then the system suddenly emitted a strong burst of X rays that researchers believed could be created only by material falling into a black hole. Although the black hole by its nature can't be seen, observers noticed in 1992 that the visible star orbits an invisible companion every 6.5 days. This orbital period implies that the dark star has a mass at least six times the Sun's. Because neutron stars can contain no more than three solar masses, this mass estimate reinforced the idea that the star must be a black hole.

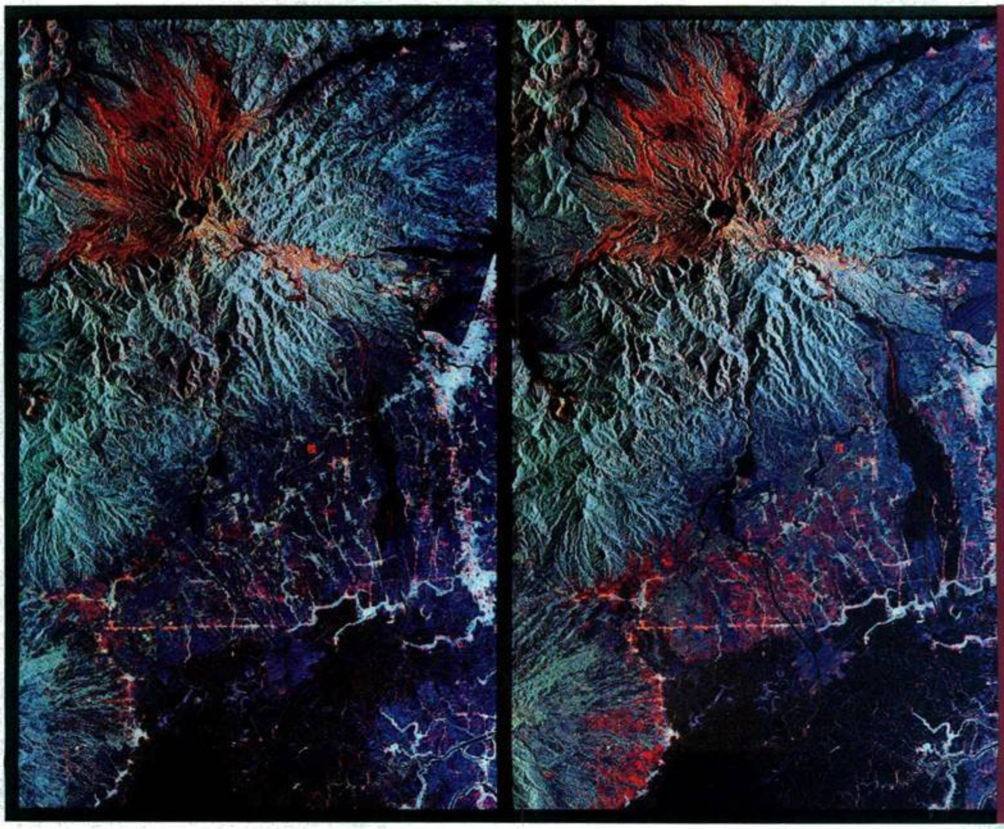
Now they have additional proof. Phil Charles of the University of Oxford and colleagues from Oxford and Keele University have measured the mass of the star more directly. As reported in the November 1, 1994 issue of the *Monthly Notices of the Royal Astronomical Society*, the scientists analyzed the spectrum of the visible star to determine the details of its orbit. Their analysis reveals the visible star contains 0.7 solar mass and the black hole contains at least 10 solar masses (their best estimate is 12 solar masses). Theorists now have to discover what kinds of stars could evolve into such an exotic duo.

Bursts in the Galactic Halo?

A team of Russian scientists believes gamma-ray bursts originate in neutron stars in the halo of matter surrounding the Milky Way Galaxy. Long one of the most puzzling inhabitants of the astronomical zoo, gamma-ray bursts shine brilliantly for a few seconds at most (see "A Burst of Gamma Rays," October 1991, and "Bursting with Surprises," March 1992).

Most astronomers agree that the high-energy bursts arise near the incredibly dense, magnetized surfaces of neutron stars. But the location of these stars raises intense debate. Before the Compton Gamma-Ray Observatory started detecting hundreds of the bursts, most thought the neutron stars resided in the disk of the Milky Way Galaxy. But when Compton found that the bursts reached Earth from all directions, many switched to the view that the stars lay far out in the universe, well beyond the confines of our Galaxy.

Now Aleksander Gurevich, Gely Zharkov, Kirill Zybin, and Mikhail Ptitsyn of the P. N. Lebedev Institute in Moscow, Russia, lend support to a third possibility: The bursts come from the vast halos of matter that surround galaxies. Reporting in *Physics Letters A* (volume 175), they contend that the Compton data show a slight increase in the number of bursts coming from the direction of the Andromeda Galaxy. That's just what would be expected if Compton's instruments are sensitive enough to detect essentially all the bursts from the uniform halo around our Galaxy, only the brightest emanating from Andromeda, and none from



NASA/JPL

SPACE SHUTTLE ENDEAVOUR'S RADAR captured Mount Pinatubo and its surroundings on April 14 (left) and October 5 (right), 1994. The main volcanic crater appears near the top of these false-color images, with the red on the high slopes indicating ash deposits from the 1991 eruption. In the nearly six months between the images, significant changes took place, particularly along the Pasig-Potrero rivers seen at lower right. The dark areas represent devastating mudflows that occurred during the 1994 summer monsoon season, when they filled the river valleys and spread out over the surrounding countryside.

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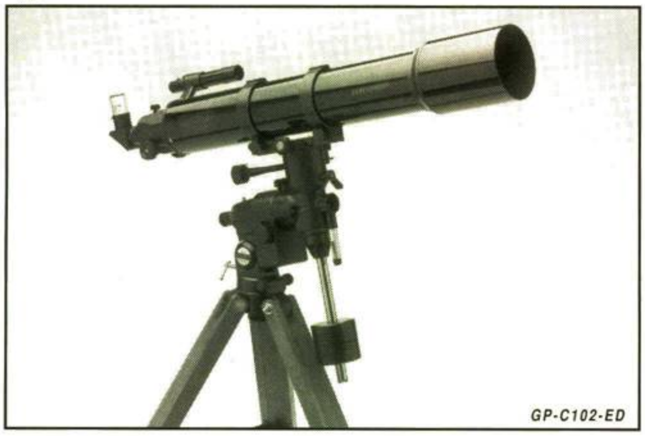
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The filters are mounted in black anodized aluminum cells with the Kodak Wratten Series engraved on each one and they are supplied in a plastic case.

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Coma Corrector

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5mm	1¼"	45°
6mm	1¼"	45°
9mm	1¼"	50°
10mm	1¼"	50°
15mm	1¼"	50°
20mm	1¼"	50°
25mm	1¼"	50°
30mm	2"	50°

2" Star Diagonal

REDUCER/CORRECTOR f/6.3 — This combination focal reducer and field corrector lens accessory works with all Celestron C5's, C8's, C11's and C14's. Now it is possible to have a dual focal ratio instrument without sacrificing image quality. The Reducer/Corrector is f/6.3 for C5, C8 and C11, f/7 for C14. The drawbacks of a dedicated f/6.3 Schmidt-Cassegrain with its much larger central obstruction (causing reduction of contrast) and the inability to utilize longer focal ratios for certain objects led us to design this four element, **fully multi-coated** accessory. Results are amazing BOTH visually and photographically. ***Far superior to competitive units!***

DIAGONAL – 2" — A standard 2" Mirror Star Diagonal. It is an improved version of the unit previously offered and it includes an adapter to accept 1.25" eyepieces. It has **multi-coated** optics and the mechanics are smooth and precision manufactured.

Reducer/Corrector f/6.3

RADIAL GUIDER — Specifically for use in prime focus, deep sky astrophotography, the Radial Guider is compact and sleek in design. It allows you to simultaneously photograph and guide through the optical tube assembly of your telescope. With the Radial Guider, the problem of differential flexure is eliminated as you are both guiding and photographing through the telescope. It includes: "T"-shaped body, prism adjustment screw, eyepiece holder and screws.

This guider is a tremendous improvement over conventional off-axis guiders. **The angle of the prism is tunable**. It has a fixed rigid camera orientation while the user is free to move the guiding eyepiece radially about 135°!

Radial Guider

MFFT-55

MFFT-55 — Celestron's Multi-Function Focal Tester-55 (MFFT-55) is a focusing aid designed to allow astrophotographers to accurately evaluate their telescope's focal plane in three main areas of interest: focus, collimation (squareness), and curvature of field. With the MFFT-55, you can focus on and off the optical axis at 3, 16, 22 and 30mm diameters in four quadrants in a single setup.

The MFFT has a black anodized tube and a glass plate with opaque and reflective coatings etched into a three zone reticle pattern. The glass plate is positioned at 55mm — the exact distance from the front face of the T-ring to an SLR film plane. It screws onto the Radial Guider to achieve "perfect" focus.

FLASHLIGHT — A flashlight with a **red LED** for star map reading and night use at the telescope. The LED does not impair night vision. Also great for bird watchers to study field guides in low light conditions without disturbing the birds. Compact at only 6" long and weighs just 2.5 oz. Two AA batteries are included.

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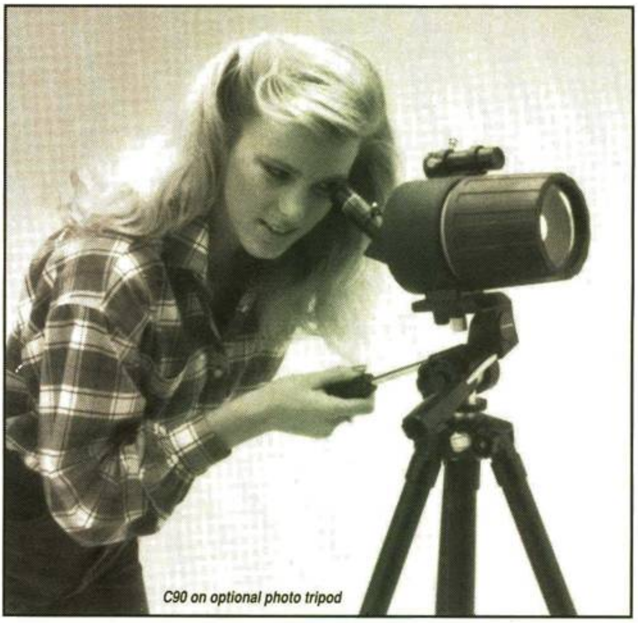
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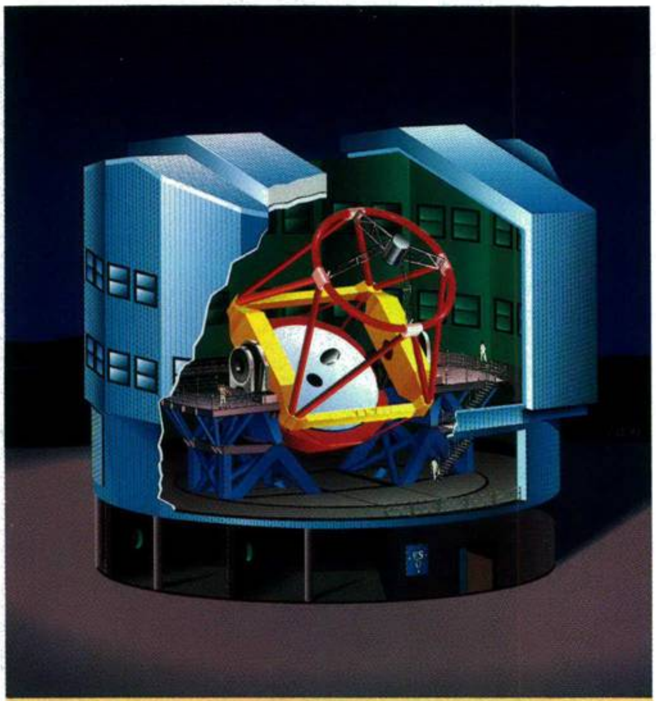
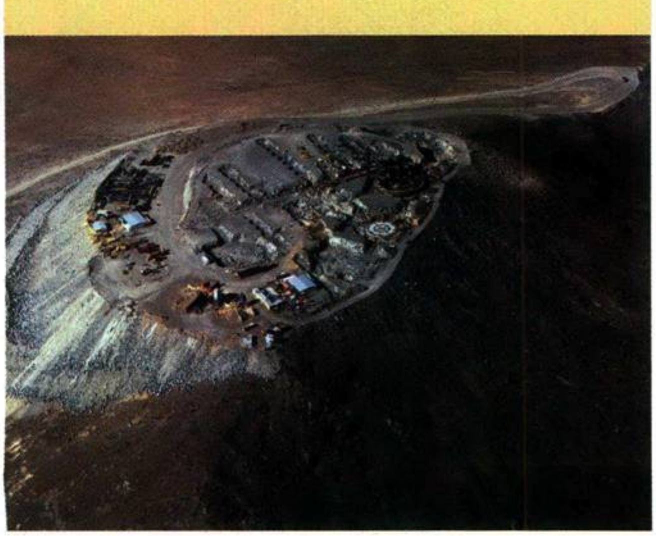


Both images by the European Southern Observatory

THE VERY LARGE TELESCOPE TAKES SHAPE on Cerro Paranal in Chile (below). In September 1994, the first of four telescope bases reached the floor level for the telescope. At the same time, workers finished pouring the foundation slab for the second scope and had nearly finished excavating the tunnels connecting the telescopes and laboratories. When the concrete tunnels are completed, they will be covered with rock so wind can flow freely over the mountaintop. Aboveground buildings would churn the air, reducing the quality of the scopes' images. The European Southern Observatory has now finalized the design of the scopes, which consists of altazimuth-mounted instruments in steel domes (top). The windowlike features are ventilation ports. The first dome should be completed by May 1995, with the first scope beginning operation in 1997.



Europeans Look Beyond 2006

During at meeting last October, the European Space Agency selected two missions to fly during a ten year period after 2006. Both projects were selected out of a field of 110 proposals, 14 of them made by Americans. One mission is an orbiting astronomical observatory that uses interferometry to search for Jupiter-sized planets around nearby stars. It will also catalog the distances, luminosities and motions of millions of stars in our Galaxy. The other, a mission to Mercury that includes an orbiter and lander, might involve the United States.

If member countries agree to increase ESA's science budget by four to five percent between 2000 and 2005, the agency might also fly a mission that attempts to detect gravity waves from such objects as binary stars and black holes. Such an effort requires the launch and careful spacing of six satellites millions of miles apart. Each craft's position would be calibrated by a network of laser beams. Also under consideration are smaller missions to study the Sun and perform X-ray, gamma-ray, and infrared astronomy.

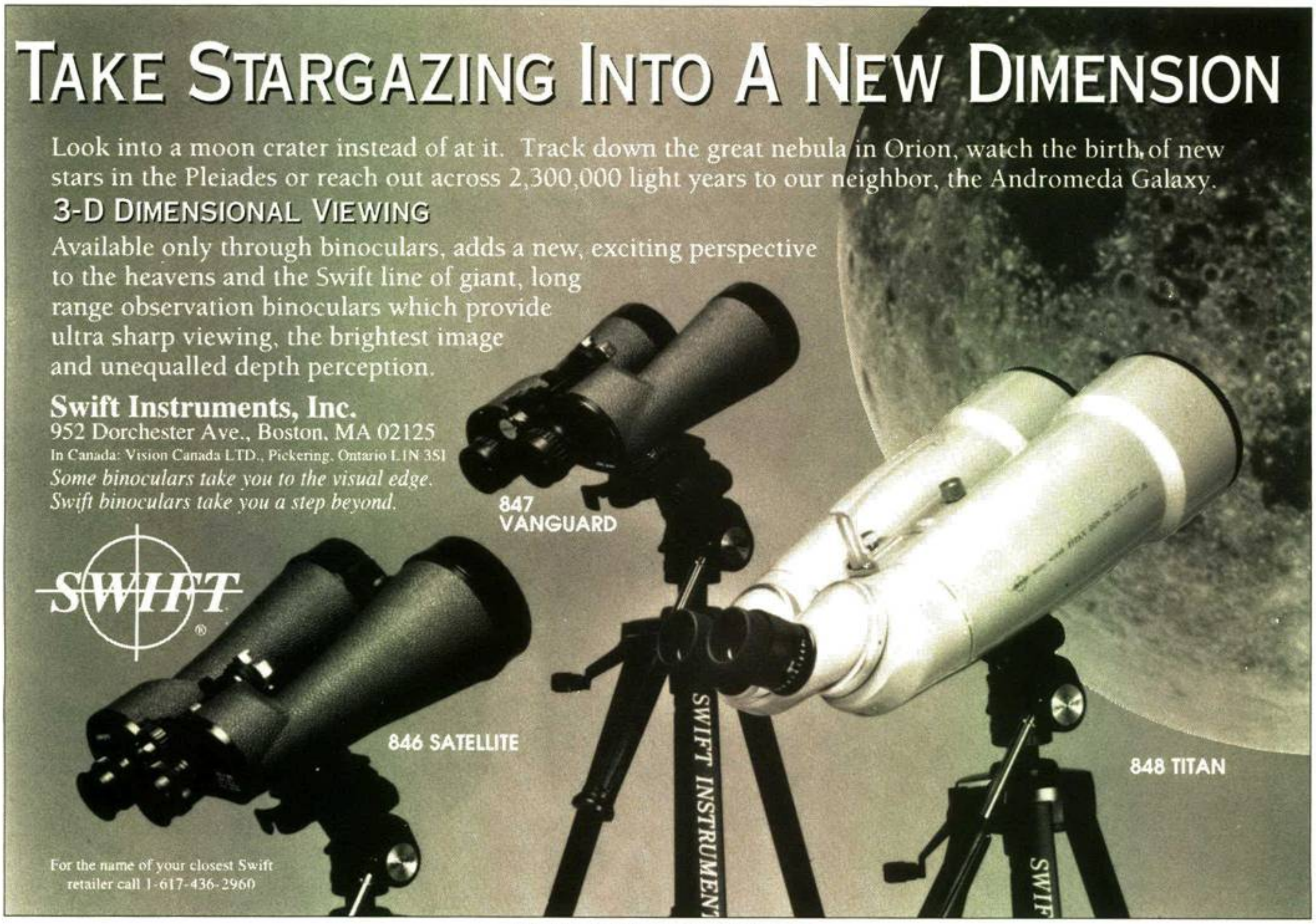
According to ESA policy, member countries do not commit money to these programs until 2000. Until then, existing money will fund preliminary study and design work.

galaxies farther away. However, astronomers need to detect many more bursts before confirming this intriguing scenario and discounting the others.

Interstellar Methylene Discovered

Thus far about 100 types of molecules have been found in interstellar space. Theory predicts that thousands should form, however, so it's comforting when another is discovered. Astronomers have for the first time found methylene (CH_2) in two interstellar clouds called the Orion KL nebula and the W51M nebula. The work was announced in the January 1, 1995 issue of the *Astrophysical Journal*.

Astronomers Mike Hollis of NASA's Goddard Space Flight Center, Phil Jewell of the National Radio Astronomy Observatory (NRAO), and Frank Lovas of the National Institute of Standards and Technology made the detection with the 12-m radio telescope at NRAO. The finding is a natural followup to the discovery two decades ago of an interstellar methylidyne radical (CH) in each of these clouds. Both CH and CH_2 are thought to form when a methyl cation (CH_3^+) combines with an electron. They are both lost by reacting with atomic oxygen. Finding the amount of each now in the cloud provides a better understanding of the chemistry of the clouds when they formed. The astronomers found the likeliest scenario is that the combination of CH_3^+ and an electron forms primarily CH_2 and a hydrogen atom rather than CH and molecular hydrogen. This agrees with the theoretical predictions of how chemistry within the clouds should operate. □



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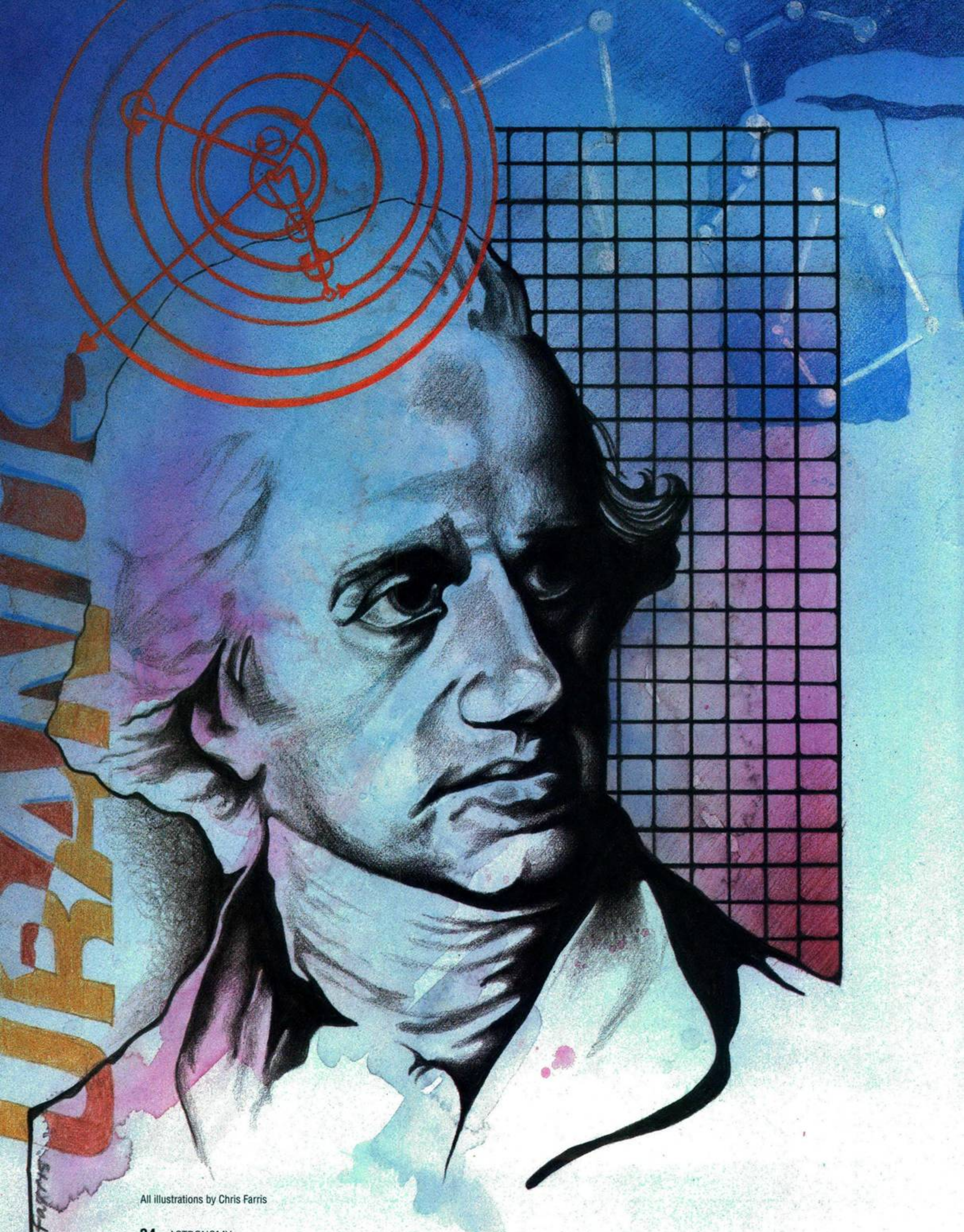


All illustrations by Chris Farris

The First New Planet

For thousands of years, observers knew of just five planets. The astronomical world shook when William Herschel's telescope revealed a new one — Uranus.

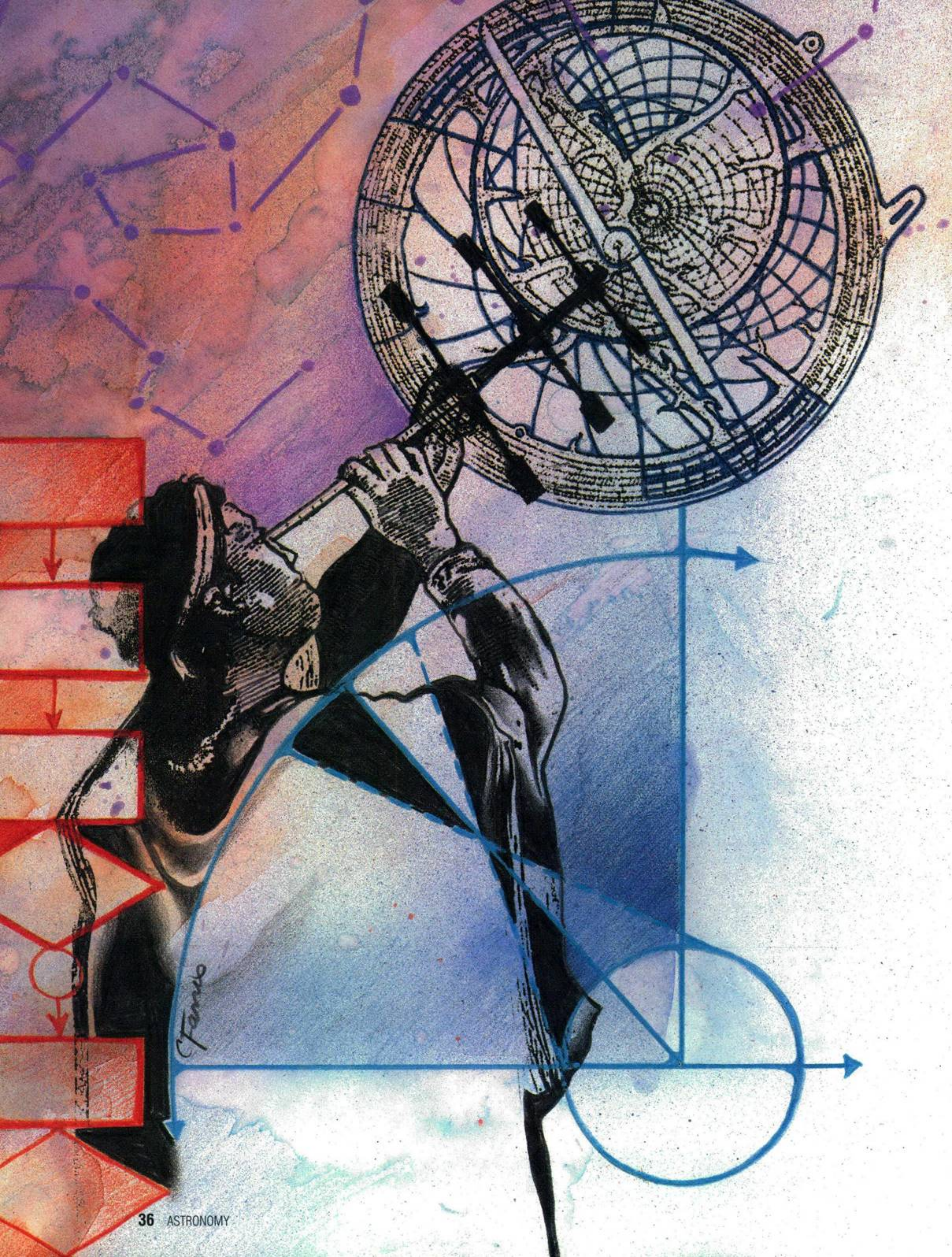
by Carl Sagan

Before we invented civilization, our ancestors lived mainly in the open, out under the sky. Before artificial lights, atmospheric pollution, and modern forms of nocturnal entertainment, people watched the stars. Star watching had practical calendrical reasons, but there was more to it than that. Even today, the most jaded city dweller can be unexpectedly moved by a clear night studded with thousands of stars. When it happens to me after all these years as a professional astronomer, it still takes my breath away.

I lie back in an open field and the sky surrounds me. I'm overpowered by its scale. It is so vast and so far away that my own insignificance becomes palpable. I'm a part of it — tiny to be sure, but everything is tiny compared to that overwhelming immensity. And when I concentrate on the stars, the planets, and their motions, I have an irresistible sense of clockwork — elegant precision working on a scale that, however lofty our aspirations, dwarfs and humbles us.

Most of the great inventions in human history — from stone tools and the domestication of fire to written language — were made by unknown benefactors. Our institutional memory of long-gone events is feeble. We do not know the name of that ancestor who first noticed that planets were different from stars. She or he lived tens, perhaps hundreds of thousands of years ago. But eventually, people all over the world understood that five, and no more, of the bright points of light that grace the night sky break lockstep with the others over a period of months, moving strangely.

Sharing the odd apparent motion of these planets were the Sun and Moon, making seven wandering bodies in all. These seven were important to the ancients, so they named the wanderers after gods — not any old gods, but the chief gods,



the ones that tell other gods (and mortals) what to do. One of the planets, bright and slow moving, was named by the Babylonians after Marduk, by the Norse after Odin, and by the Romans after Jupiter, in each case after the king of the gods. The faint, fast-moving one that was never far from the Sun the Romans named Mercury, after the messenger of the gods. The most brilliant of them they named Venus, after the goddess of love and beauty; blood red Mars, after the god of war; and the most sluggish of the bunch Saturn, after the god of time. These allusions were the best our ancestors could do. They possessed no scientific instruments beyond the naked eye. They were confined to Earth and had no idea that it too is a planet.

When ancient scholars designed the week — a period of time with no intrinsic astronomical significance unlike the day, month, and year — they gave it seven days and named each after one of the seven anomalous lights in the night sky. We can readily make out the remnants of this convention. In the English language, Saturday is Saturn's day. Sunday and Monday are clear enough. Tuesday through Friday are named after the gods of the Saxon and Teutonic invaders of Celtic/Roman Britain. Wednesday, for example is Odin's (Wodin's) day; Thursday is Thor's day. Saturday came from the Romans, but the names of the other days have Germanic roots.

This collection of seven gods, seven days, and seven worlds — the Sun, Moon, and five wandering planets — entered the perceptions of people everywhere. The number seven began to acquire supernatural connotations. There were seven "heavens," the transparent spherical shells centered on Earth that were imagined to make these worlds move. The outermost, seventh heaven, was where the "fixed" stars were imagined to reside. There were seven days of creation (if we include God's day of rest), seven deadly sins, seven evil demons in Sumerian myth, seven vowels in the Greek alphabet (each affiliated with a planetary god), and seven alchemical "bodies" (gold, silver, iron, mercury, lead, tin, and copper, each associated with a planet). Seven is a lucky number. St. Augustine obscurely argued for the mystic importance of seven on the grounds that three "is the first whole number that is odd" (what about one?), "four the first that is even" (what about two?), and "of these . . . seven is composed." And so on. Even in our times, these associations linger.

Several centuries ago, people disbelieved Galileo's discovery of the four satellites of Jupiter — hardly planets — on the grounds that it challenged the precedence of the number seven. As acceptance of the Copernican system grew, the solar system had only six planets (Mercury, Venus, Earth, Mars, Jupiter, and Saturn). So learned academic arguments arose that explained why there had to be six. For example, six is the first "perfect" number, a number equal to the sum of its divisors (1 + 2 + 3). And anyway, there were only six days of creation, not seven. People mystically accommodated from seven worlds to six.

As those adept at numerological mysticism adjusted to the Copernican system, this self-indulgent mode of thinking spilled over from planets to moons. Earth had one moon; Jupiter had the four Galilean moons. That made five. Clearly one was missing. (Don't forget: Six is the first perfect number.) The science historian I. Bernard Cohen of Harvard University has pointed out that after Huygens discovered Saturn's moon Titan in 1655, he actually gave up searching for other moons because it was apparent from such arguments that no more were to be found.

Sixteen years later, ironically with Huygens in attendance, Giovanni Cassini of the Paris Observatory discovered a seventh moon — Iapetus, a bizarre world circling Saturn outside of Titan's orbit. Shortly after, Cassini discovered Rhea, the Saturnian moon interior to Titan.

When astronomers made claims of new worlds in the late eighteenth century, the force of such numerological arguments had much dissipated. Still, it was with a real sense of surprise that people in 1781 heard about a new planet discovered through a telescope. New moons were comparatively unimpressive, especially after the first six or eight. That there were new planets to be found and that humans had devised the means to do so were both considered astonishing. If there is one previously unknown planet, there may be many more — in

Saturday 17th
I looked
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this solar system and in others. Who can tell what might be found if a multitude of new worlds is hiding in the dark?

The discovery wasn't even made by a professional astronomer but by William Herschel, a musician whose relatives had come to Britain with the family of another anglicized German, the reigning monarch and future oppressor of the American colonists, George III. It became Herschel's wish to call the planet George ("George's Star," actually) after his patron but, providentially, the name didn't stick. Instead, the planet that Herschel found (he thought it was a comet at first) is called Uranus, after the ancient Greek sky god who was Saturn's father and thus the grandfather of the Olympian gods.

We no longer consider the Sun and Moon to be planets and count Uranus as the seventh planet in order from the Sun. The four outer, Jovian planets turn out to be very different from the four inner, terrestrial planets. Pluto is a separate case, fitting into neither category.

As the years passed and the quality of astronomical instruments improved, we began to learn more about distant Uranus. What reflects the dim sunlight back to us is no solid surface, but atmosphere and clouds — just as for Jupiter, Saturn, and Neptune. The air on Uranus is made of hydrogen and helium, the two simplest gases. Methane and other hydrocarbons are also present. Just below the clouds visible to Earthbound observers are enormous quantities of ammonia, hydrogen sulfide, and, especially, water.

Deep inside Jupiter and Saturn the pressures are so great that atoms sweat electrons and the air becomes a metal. That does not seem to happen on less massive Uranus because the pressures at depth are less. Still deeper inside Uranus, under the crushing weight of the overlying atmosphere, is a rocky surface — discovered only by its subtle tugs on the planet's moons and wholly inaccessible to view. A big Earth-like planet is hiding down there, swathed in an immense blanket of air.

Earth's surface temperature is due to the sunlight it intercepts. Turn off the Sun and the planet soon chills — not to trifling Antarctic cold, not just so cold that the oceans freeze, but to a cold so intense that the very air condenses, forming a 10-meter-thick layer of oxygen and nitrogen snows covering the whole planet. The little bit of energy that trickles out from Earth's hot interior would be insufficient to melt these snows. But for Jupiter, Saturn, and Neptune, it's different. Their interiors pour out about as much heat as their surfaces acquire from the warmth of the distant Sun. Turn off the Sun and they would be affected only a little.

But Uranus is different: Uranus is an anomaly among the Jovian planets. Uranus is like Earth, with very little intrinsic heat pouring out. We have no good understanding of why this should be — why Uranus, which in many respects is so similar to Neptune, should lack a potent source of internal heat.

Uranus is different in another way: It lies on its side as it goes around the Sun. During the 1990s, the south pole is heated by the Sun, and it is this pole that Earthbound observers see when they look at Uranus. It takes Uranus 84 Earth years to go around the Sun. So in the 2030s, the north pole will be Sunward (and Earthward). In the 2070s the south pole will be pointing to the Sun again. In between, Earthbound astronomers will be looking mainly at equatorial latitudes.

All the other planets spin much more upright in their orbits. No one is sure why Uranus spins anomalously. The most promising suggestion is that sometime in its early history, billions of years ago, it was struck by an Earth-sized rogue planet that was traveling in a highly eccentric orbit. Such a collision, if it happened, must have caused much tumult in the Uranus system. For all we know, there may be other vestiges of ancient havoc still left for us to find. But Uranus' remoteness tends to guard the planet's mysteries.

In 1977 a team of scientists led by James Elliot (then of Cornell University) accidentally discovered that Uranus, like Saturn, has rings. The scientists were flying over the Indian Ocean in a special NASA airplane, the Kuiper Airborne Observatory, to witness Uranus pass in front of, or occult, a distant star. The observers were surprised to find that the star winked on and off several times just before it passed behind Uranus and its atmosphere and then several times more just after it emerged. Because the patterns of winking on and off were the same before and after the occultation, this finding (and much subsequent work) has led to the discovery of nine thin, dark rings surrounding the planet, giving it the appearance of a bull's-eye in the sky.

Surrounding the rings, Earthbound astronomers understood, were the concentric orbits of the five moons then known: Miranda, Ariel, Umbriel, Titania, and Oberon. They're named after characters in Shakespeare's *A Midsummer Night's Dream* and *The Tempest* and in Alexander Pope's *The Rape of the Lock*. Two of them, Titania and Oberon, were found by Herschel himself. The innermost of the five, Miranda, was discovered as recently as 1948, by my teacher

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Gerard Kuiper. (He so named it because of the words spoken by Miranda, the heroine of *The Tempest*: "O brave new world, That has such people in't." To which Prospero replies, "'Tis new to thee." Just so. Like all other worlds in the solar system, Miranda is 4.5 billion years old.) I remember how great an achievement people back then considered the discovery of a new moon of Uranus.

A revolution in our understanding of the Uranus system — the planet, its rings, and moons — began on January 24, 1986. On that day, after a journey of 8½ years, the Voyager 2 spacecraft sailed near Miranda. Uranus' gravity then flung the spacecraft on to Neptune. Voyager returned 4,300 close-up pictures of the Uranus system and a wealth of other data.

Planetary scientists found Uranus to be surrounded by an intense radiation belt, electrons and protons trapped by the planet's magnetic field. Voyager flew through this radiation belt, measuring the magnetic field and the trapped particles as it went. It also detected — in changing timbres, harmonies, and nuance, but mainly in fortissimo — a cacophony of radio waves generated by the speeding, trapped particles. Something similar exists at Jupiter, Saturn, and Neptune, but always with a theme and counterpoint characteristic of each world.

On Earth the magnetic and geographical poles are quite close together. On Uranus, the magnetic axis and the axis of rotation tilt away from each other by some 60 degrees. No one yet understands why. Some have suggested that we are catching Uranus in a reversal of its north and south magnetic poles, as periodically happens on Earth. Others propose that this too is the consequence of that mighty, ancient collision that knocked the planet over. But we do not know.

Among the principal glories of Voyager's encounter with Uranus were the pictures. With the two television cameras on the spacecraft, astronomers discovered 10 new moons, determined the length of the day in the clouds of Uranus (about 17 hours), and studied about a dozen rings. The most spectacular pictures were those returned from the five larger, previously known moons, especially the smallest of them, Kuiper's Miranda. Its surface is a tumult of fault valleys, parallel ridges, sheer cliffs, low mountains, impact craters, and frozen floods of once-molten surface material. This turmoiled landscape is unexpected in a small, cold, icy world so distant from the Sun.

Perhaps the surface was melted and reworked in some long-gone epoch when a gravitational resonance between Uranus, Miranda, and Ariel pumped energy from the planet into Miranda's interior. Or perhaps we are seeing the results of the primordial collision that may have knocked Uranus over. Or just conceivably, maybe a wild careening world utterly destroyed Miranda, dismembered it, and blasted it into smithereens, with many collision fragments still left in the moon's orbit. The shards and remnants, slowly colliding, gravitationally attracting each other, may have reaggregated into just such a jumbled, patchy, unfinished world as Miranda is today.

For me, there's something almost eerie about the pictures of dusky Miranda, because I can remember so well when it was only a faint point of light almost lost in the glare of Uranus, discovered through great difficulty by dint of the astronomer's skills and patience. In only half a lifetime it has gone from an undiscovered world to a destination, one whose ancient and idiosyncratic secrets have been at least partially revealed. ☐

Carl Sagan is the David Duncan Professor of Astronomy and Space Sciences at Cornell University in Ithaca, New York. This article is adapted from his new book Pale Blue Dot: A Vision of the Human Future in Space *(Random House).*

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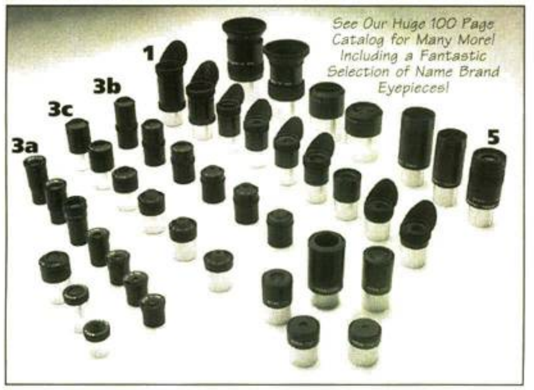
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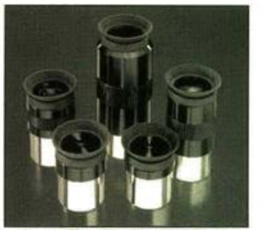

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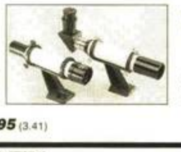

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POLARIS, the Code-Blue Star

The North Star's variable heart pulsed regularly for over a century, until it mysteriously stopped beating last year.

by Robert Zimmerman

Of all the stars in the sky, Polaris is probably the only one that almost all Northern Hemisphere dwellers can name and identify. This eminence stems from its unchanging position. As Earth spins on its axis each day, the two spots directly above the poles do not wheel across the sky but stay fixed in the heavens. Since the beginnings of written history, Polaris has held this fortuitous position in the Northern Hemisphere and so has come to represent faithfulness, dependability, and constancy in most cultures.

As astronomers observed this star in greater detail, however, they found it to be far less constant in brightness than its position implied. In the middle of the 19th century, astronomers Ludwig Seidel and Julius Schmidt independently recorded variations in the star's light. In 1899 W. W. Campbell of Lick Observatory identified a recurring Doppler shift in Polaris' spectrum, indicating that the star's radius was expanding and shrinking repeatedly. Then in 1911, Danish astronomer Ejnar Hertzsprung determined that the star's brightness varied by about ten percent in a period of just under four days, and just two years later Dutch astronomer Antonie Pannekoek identified Polaris as a low-amplitude Cepheid variable, the kind whose brightness varies regularly over periods of days or weeks.

Observers of the starry heavens have watched Cepheid variables dependably pulse in and out with exacting precision since John Goodricke first noticed the changing light of Delta Cephei in 1784. Their variability was, as Shakespeare so aptly put it, "as constant as the northern star." Unfortunately, for those of us who crave dependability in our lives, Polaris has recently thrown a big monkey wrench into the predictability of Cepheid variables. As of 1994, the North Star ceased pulsating, transforming from a variable into a constant star, as constant now in light as it appears in position.

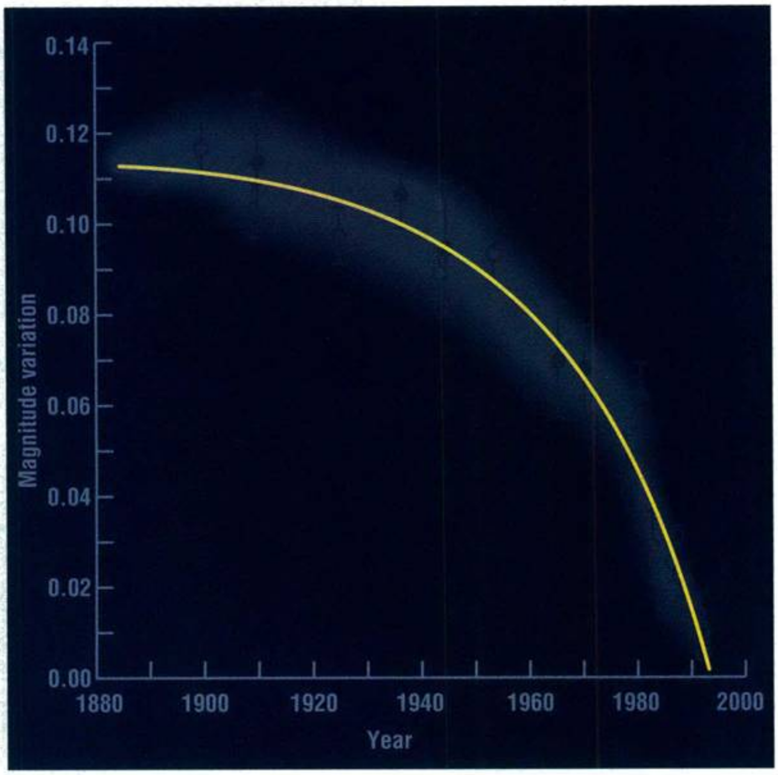
Cepheid variable stars play a vital role in understanding the distance scale of the universe and how massive stars evolve. Astronomers can calculate the distances to Cepheids because these stars vary in brightness and pulsate in size with periods directly proportional to their intrinsic brightness. Comparing a Cepheid's apparent brightness to its intrinsic brightness derived from the period yields the distance, and the technique can work as far away as the Virgo Cluster of galaxies (see "How Far to Virgo?" on page 48). A Cepheid's variability also marks a time in the late stages of a massive star's life when its interior becomes unstable. The pulsations that result help astronomers "see" inside the star so they can examine the structural changes that take place as the star evolves.

For decades Polaris appeared to be a normal Cepheid, a yellowish white supergiant star (classified as an F7Ib to F8Ib star) with a surface temperature of about 6000 kelvins. Beginning in the 1940s, however, astronomers began to notice strange albeit small changes in Polaris' period of oscillation. The time between brightness peaks slowly lengthened from 3.96809 days in the early years of the 20th century to 3.96961 in 1945 to 3.97156 in 1983, a total of about 300 seconds over 83

STARS WHEEL ACROSS THE SKY, circling the nearly fixed star Polaris. Although the North Star's position doesn't change, its brightness has varied regularly, at least until last year.

Jim Baumgardt

POLARIS WENT "CODE BLUE" in 1994, when the brightness changes that marked its life as a Cepheid variable finally ceased.



ASTRONOMY: Steven G. Davis

years. This type of change, though not unusual for many Cepheids, was still somewhat larger than most, and steadily increasing with time.

Then in 1983, A. Arellano Ferro of the Universidad Nacional Autonoma de Mexico in Mexico City noticed that since the 1940s the variations in the star's light, its amplitude, had been declining as well. By 1989 astronomers realized that this decline was accelerating at an astonishingly fast rate and that within approximately five years the amplitude might disappear altogether. By 1993 Don Fernie of the David Dunlap Observatory of the University of Toronto confidently said that "the plunge toward zero seems irrevocable. The star seems destined to stop pulsating by 1994." And Fernie was right.

This cessation of a Cepheid's pulsations seems unique in the annals of astronomy. The only other star known to have ceased oscillating, RU Camelopardalis, did so in the middle 1960s, only to sputter back to life erratically in recent years. But with a strange spectrum showing strong lines of carbon, RU Cam is an oddball Cepheid that doesn't fit easily into any modern theory of stellar evolution. Another Cepheid, Y Ophiuchi, has shown some evidence of an amplitude decline, from 0.7 to 0.5 magnitude, but the star still continues its regular oscillations every seventeen days.

Whether Polaris will stay constant or begin to pulse again like RU Camelopardalis, its transformation has challenged much modern theory about how stars evolve.

All Cepheids have roughly the same temperature and are either bright giant or supergiant stars. That places them in the same general area of the Hertzsprung-Russell diagram, a diagram that plots a star's intrinsic brightness against its temperature or spectral type. Astronomers call this region the instability strip because all stars there pulsate (see diagram on opposite page). Like all stars, Polaris spent most of its life on the main sequence, converting hydrogen into helium and releasing energy in the process. Once the hydrogen in the star's core is used up, the star fuses helium into carbon, carbon into oxygen, and so on, the star's mass being transmuted into progressively heavier elements as it consumes the fuel. As the star moves off the main sequence to become a giant, its spectrum and magnitude change, which causes its position on the H-R diagram to change as well.

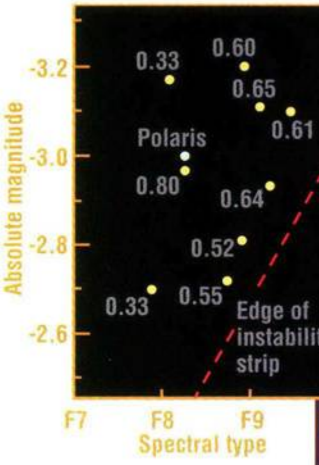
As the star starts its giant phase, it slowly expands and its surface temperature cools. The increase in size, and thus luminosity, and decrease in temperature cause the star to move up and to the right on the H-R diagram. Later, when the star begins to burn heavier elements like helium, its size shrinks, lowering the luminosity, and temperature rises, so it moves down and left on the H-R diagram and into the instability strip. For massive stars, those five to ten times the Sun's mass, this journey brings them across the instability strip several times in their lifetime.

For even more massive Cepheid variables, the star can drift in and out of the instability strip in this manner as many as five times, its color changing from red to white to red to white again and again. And each time the star re-enters the strip, it begins to pulsate and thus fluctuates in brightness, becoming a variable star.

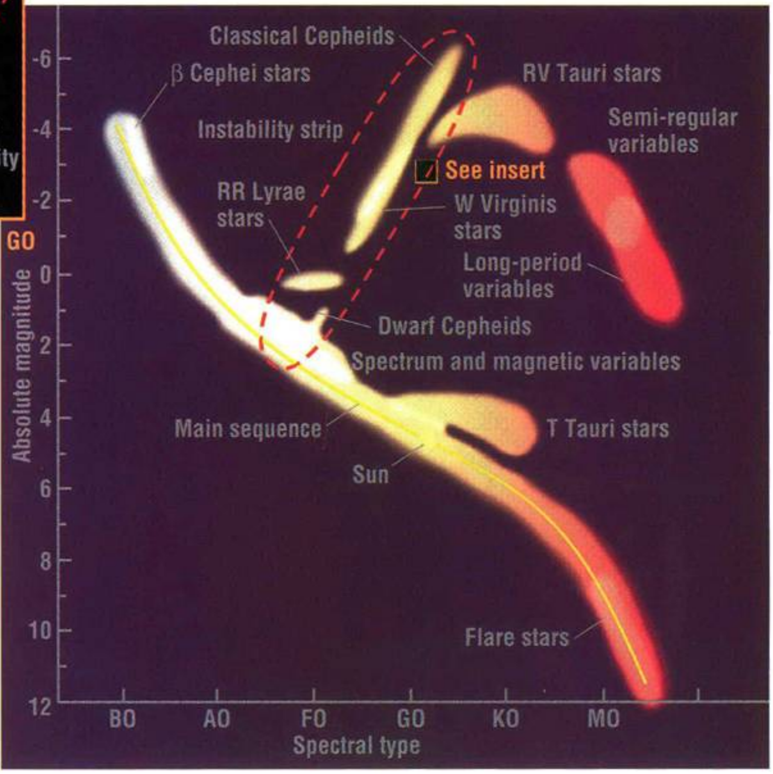
Most Cepheid variables pulsate with remarkable precision, their periods changing by less than seconds over many decades. Additionally, each journey across the instability strip can last as long as 50,000 years. Other types of variable stars, such as dwarf Cepheids, RR Lyrae stars, and W Virginis stars, also inhabit the instability strip, but none pulsate as consistently or shine as brightly as the Cepheids.

Although stellar evolutionary theory predicts how a star behaves in the instability strip, theorists don't know the exact combination of temperature and absolute magnitude that causes a star to pulsate or the time span of the evolutionary stages. Astronomers had thought that the transition of a Cepheid from variable to constant would take anywhere from 1,000 to 10,000 years. But Polaris, as well as RU Camelopardalis, has shown that a star can change its stripes in an astronomical instant.

The speed with which both Polaris and RU Camelopardalis stopped pulsating means that an astronomer in a single lifetime might be able to see numerous Cepheids make this transition. This in turn would allow scientists to delineate more quickly the limits of the instability strip. Hence the search is intensifying for other stars that behave like Polaris. Though other low-amplitude Cepheids would seem to be the best candidates, their small amplitude makes them difficult to identify, and therefore few are known. Paul Butler of the University of Maryland recently discovered that Gamma Cygni is a Cepheid and has the lowest amplitude ever found, less than 0.01 magnitude over a period of nearly 12 days. This star might just be leaving or entering the strip, and its tiny amplitude raises the possibility that many similar stars previously considered constant might actually be variables.



THE INSTABILITY STRIP is a region of the Hertzsprung-Russell diagram where all stars should vary. Yet Polaris, which lies firmly in the strip and is surrounded by variable stars (left; numbers represent magnitude variation), now shines constantly.



ASTRONOMY: Steven G. Davis

Polaris itself continues to be a puzzle. Having settled into a constant state, the North Star still sits comfortably within the instability strip, retaining a magnitude and color similar to those of many other stars that continue to pulsate dramatically. RT Aurigae, for example, appears almost identical to Polaris in spectrum and magnitude, yet its light varies by almost a full magnitude every 3.73 days. Other Cepheid variables, even redder than Polaris and thus nearer the edge of the instability strip, continue to pulsate energetically. As Fernie points out, "There is as yet no adequate understanding of what sets the amplitude of a Cepheid."

No one knows whether Polaris will remain constant in the future, so astronomers will continue to monitor the star closely. Recent evidence indicates that the star's oscillations may gasp and flutter for a few more years.

By its transformation to constant light, the North Star has managed to test the theories of modern astronomers. It would be a mistake for anyone to assume the star will not do so again. □

Robert Zimmerman works as a freelance writer and filmmaker in New York City.

The dense central region of the **Virgo Cluster**

How Far to Virgo?

Two breakthrough measurements of Cepheid variable stars in the Virgo Cluster of galaxies have narrowed estimates of the size and age of the universe. But fierce controversy lingers.

by Ken Croswell

The plan looked good. For decades astronomers had been at one another's throats over the age of the universe, and they thought they could resolve their feud by using NASA's Hubble Space Telescope. The hawk-eyed telescope would scrutinize galaxies in the Virgo Cluster, whose location anchors the extragalactic distance scale. The distance scale, in turn, determines the Hubble constant, a number that gives the rate at which the universe expands, and indicates the universe's age.

To measure the distance to the Virgo Cluster, the Hubble Space Telescope would look for Cepheid variable stars in the cluster's spiral galaxies. Cepheids are pulsating stars whose intrinsic brightness astronomers know. By comparing a Cepheid's apparent brightness to its real brightness, an astronomer can calculate how far away the Cepheid, and its host galaxy, is. Combining the distance of a Virgo Cluster galaxy and its redshift (the speed at which it recedes from Earth) would yield the long-sought Hubble Constant.

Things didn't work out quite that way. While Hubble's vision was blurred by a faulty mirror, a team led by Michael Pierce of Indiana University scooped NASA's pricey telescope by arming a telescope in Hawaii with a powerful camera that spotted three Cepheids in one Virgo galaxy. "The evidence strongly suggests that the extragalactic distance scale is now established," Pierce says, "and the Hubble constant is around 85 kilometers per second per megaparsec." In short, Pierce contends, the great dispute is over at last.

Other astronomers vehemently disagree. "I think it's absurd," says Wendy Freedman of the Carnegie Observatories in Pasadena, California, an expert on Cepheids. "The controversy is not over. To say, based on three candidate Cepheids, that the controversy is over doesn't make any sense."

A month after Pierce published his result, Freedman and her colleagues announced that the Hubble Space Telescope had discovered 20 Cepheids in another Virgo galaxy. Although her distance for the Virgo Cluster matches that of Pierce's team, Freedman says it will be years before astronomers agree on the number they are all fighting about — the hotly disputed Hubble constant.

Welcome to the Hubble War

The Hubble constant is certainly worth fighting over: It measures the rate at which the universe is expanding and indicates its age. Many astronomers believe the universe is expanding slowly and that the Hubble constant is low, between 40 and 50 kilometers per second per megaparsec. (A parsec is 3.26 light-years.) If so, the universe is old, between 13 and 22 billion years old, because a slowly expanding universe would take a long time to attain its present size.

In recent years, though, many astronomers have measured a much higher value for the Hubble constant, between 80 and 90 kilometers per second per megaparsec (see "Candles to Light the Night," September 1994). If this higher value is correct, it implies that the universe is young, with an age between 7 and 11 billion years. Such a youthful universe poses a paradox, because some stars are thought to be 15 billion years old.

In principle, determining the Hubble constant is simple: Just divide a galaxy's redshift (in kilometers per

> "The extragalactic distance scale is now established, and the Hubble constant is around 85 kilometers per second per megaparsec."
> — Michael Pierce

Anglo-Australian Telescope Board

second) by its distance (in megaparsecs) and you've got the answer. Measuring the redshift is easy; so is measuring the distance, if the galaxy is close enough for you to see its Cepheids. These bright yellow stars pulsate, contracting and expanding periodically, waxing and waning in brightness. The longer its pulsation period, the bigger and brighter the Cepheid, so observing its period reveals the star's mean intrinsic brightness, its average brightness output. Comparing this with the Cepheid's mean apparent brightness then yields the distance to both the star and its galaxy. For a given redshift, the smaller the galaxy's distance, the greater the Hubble constant.

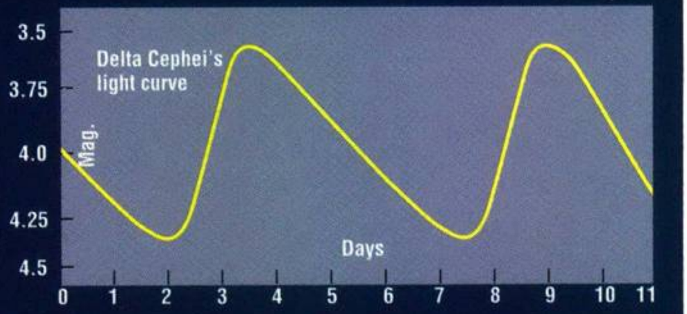
Unfortunately, until recently Cepheids had been seen only in nearby galaxies, which are perturbed by the gravity of our Galaxy and others. As a result, the redshifts of nearby galaxies do not fully reflect the universe's expansion and so do not reveal the Hubble constant. For most of this century, astronomers have therefore looked with great longing toward the Virgo Cluster of galaxies. Although no one knew the cluster's exact distance, astronomers did know that Virgo was far enough away that they could use it to probe the universe's expansion, yet close enough that someday they would detect the cluster's Cepheids, determine its distance, and thereby establish the Hubble constant.

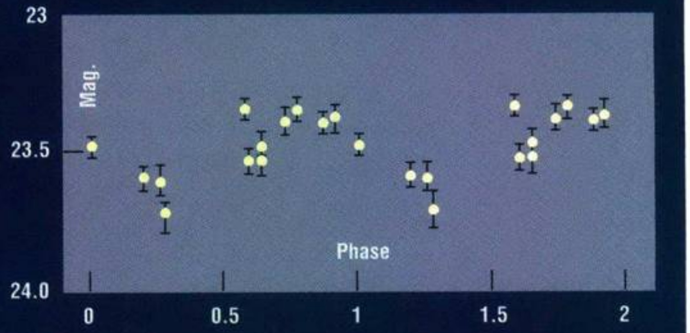
The Best Yardstick

How Astronomers Use Cepheids as Distance Indicators

The variability of the first Cepheids, Eta Aquilae and Delta Cephei (right, top), was discovered in 1784. Over the decades, many other stars mimicking the behavior of these two stars turned up. In 1907 Henrietta Swan Leavitt discovered a linear relation between the average luminosity of these stars and the period over which they vary. The longer the star's period the greater its luminosity, or true brightness. Once they know how bright the star really is, astronomers can measure how bright it appears and figure out its distance.

Astronomer Michael Pierce and his team used Cepheids like S1451 in the galaxy NGC 4571 (right, bottom) to calculate the distance to the Virgo Cluster.

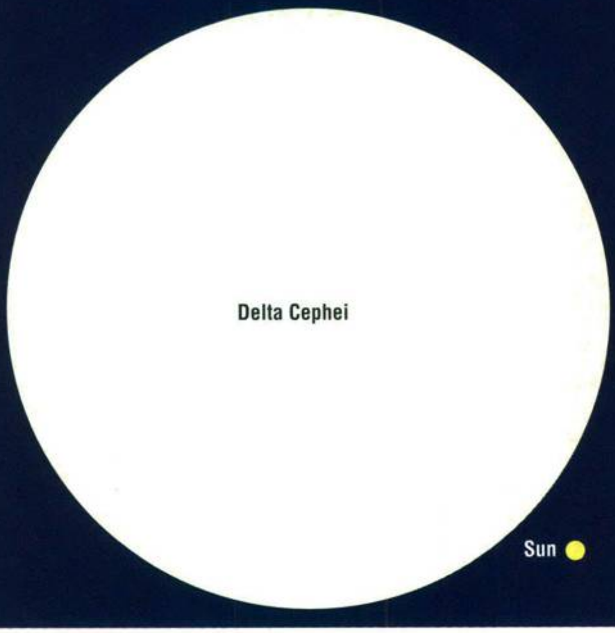




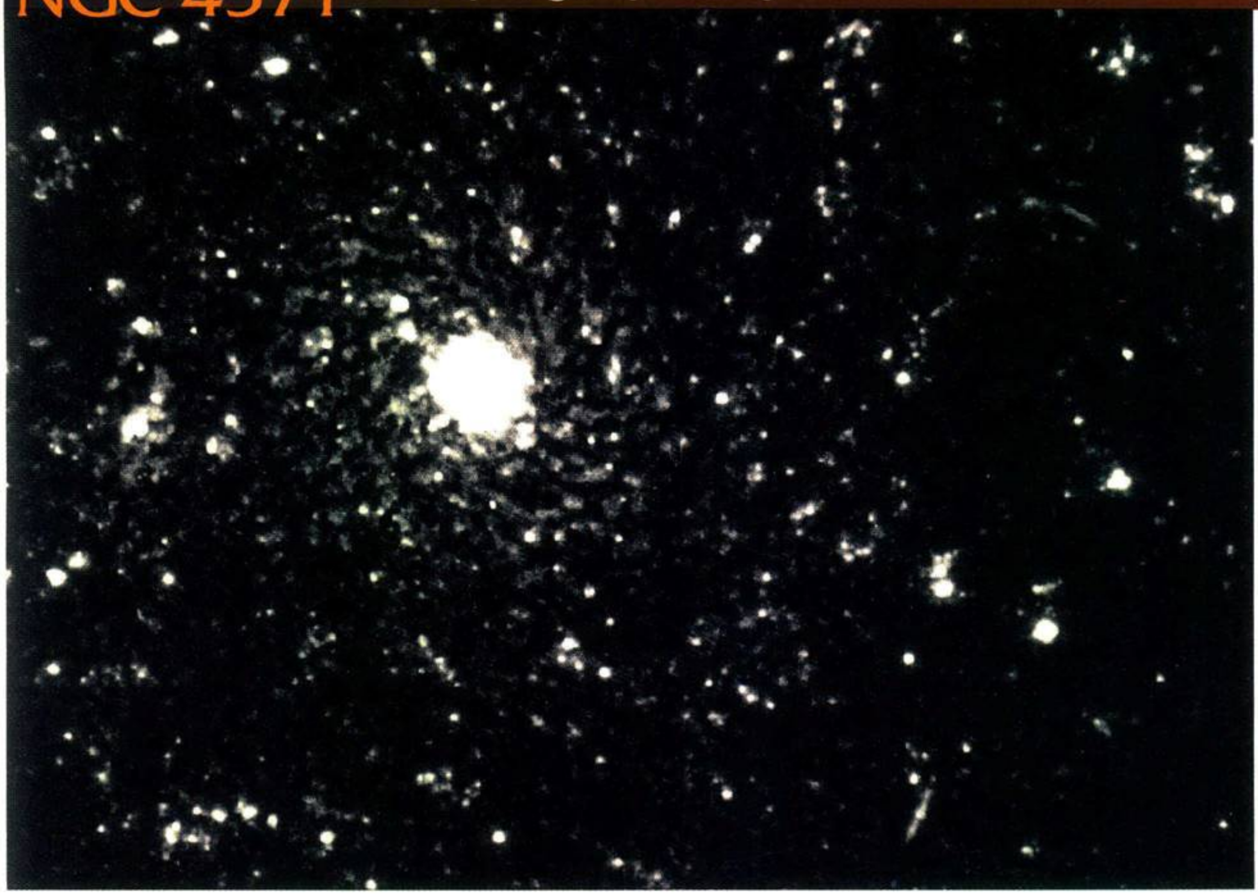
What Makes Delta Cephei Tick

The prototypical Cepheid variable is a yellowish-white supergiant star with an average diameter 50 times that of the Sun. The outer layers of Delta Cephei (and other Cepheids) pulsate with great regularity. Instabilities inside Delta Cephei cause the pulsations, oscillating the outer layers like a spring. These oscillations cause the star's temperature, size, and brightness to vary. At maximum luminosity Delta shines with the light of 3,000 Suns, making it bright enough to be seen in moderately distant galaxies.

Magnitude = 3.5 to 4.4
Diameter averages 50 times that of the Sun
Luminosity, at maximum, is 3,000 times that of the Sun
Spectral type = F5 to G2
Period = 5.366 days
Distance = 1,000 light-years



NGC 4571 — the spiral galaxy used by the Pierce team



Dominion Astrophysical Observatory

Cepheids in Virgo

That someday has arrived. On September 29, 1994, Michael Pierce and his colleagues published in *Nature* their investigation of a spiral galaxy in Virgo named NGC 4571. "What allowed us to succeed where others had failed was the development of the high-resolution camera, called HRCam, on the Canada-France-Hawaii Telescope on Mauna Kea," he says. This camera corrects distortions caused by atmospheric turbulence and provides a much sharper view of a galaxy's stars, including its Cepheids, than the traditional cameras did.

These Cepheids revealed NGC 4571's distance. Pierce's distance is small and thus his Hubble constant high. The Cepheids indicate that NGC 4571 is only 15 megaparsecs away. By assuming that this is also the distance to the entire Virgo Cluster, he finds the Hubble constant to be 87 ± 7 kilometers per second per megaparsec. This impacts the controversy over the Hubble constant, because the two warring sides claim different distances for the Virgo Cluster. Those who think the Hubble constant is high say that Virgo is only 14 to 15 megaparsecs away, while those who favor a low Hubble constant place it much farther, at a distance of 21 to 23 megaparsecs.

Pierce's team began work in 1991, after problems with Hubble surfaced. "We were as upset as anyone when the problems with Space Telescope became apparent," says Pierce. "But given my interest in the distance-scale problem, I didn't want to wait around for possibly five years to see if the fix was going to be made. I wanted to know what the distance to the Virgo Cluster based on Cepheids was." The team completed observations in 1993, before Hubble was fixed. Pierce does not plan to observe Cepheids in other Virgo galaxies, for Hubble now gives sharper views that will allow astronomers to obtain accurate distances. Pierce believes that he and the Hubble group will achieve the same results. "Because we are confident in our work," says Pierce, "we fully expect that in the end their distance will agree with ours."

In 1994, after Hubble was repaired, Wendy Freedman and her colleagues took aim at M100, another Virgo spiral. "When we first started to look for Cepheids in M100, they jumped out. It was incredibly easy, much easier than anticipated." Her

> "I hope you're not believing all the nonsense in the press. We need to look at type Ia supernovae. They are among the best standard candles we know." — Allan Sandage

team found a relatively small distance to the galaxy, 17 megaparsecs, and a high Hubble constant, 80 ± 17. Within the uncertainties, these numbers agree with those of Pierce.

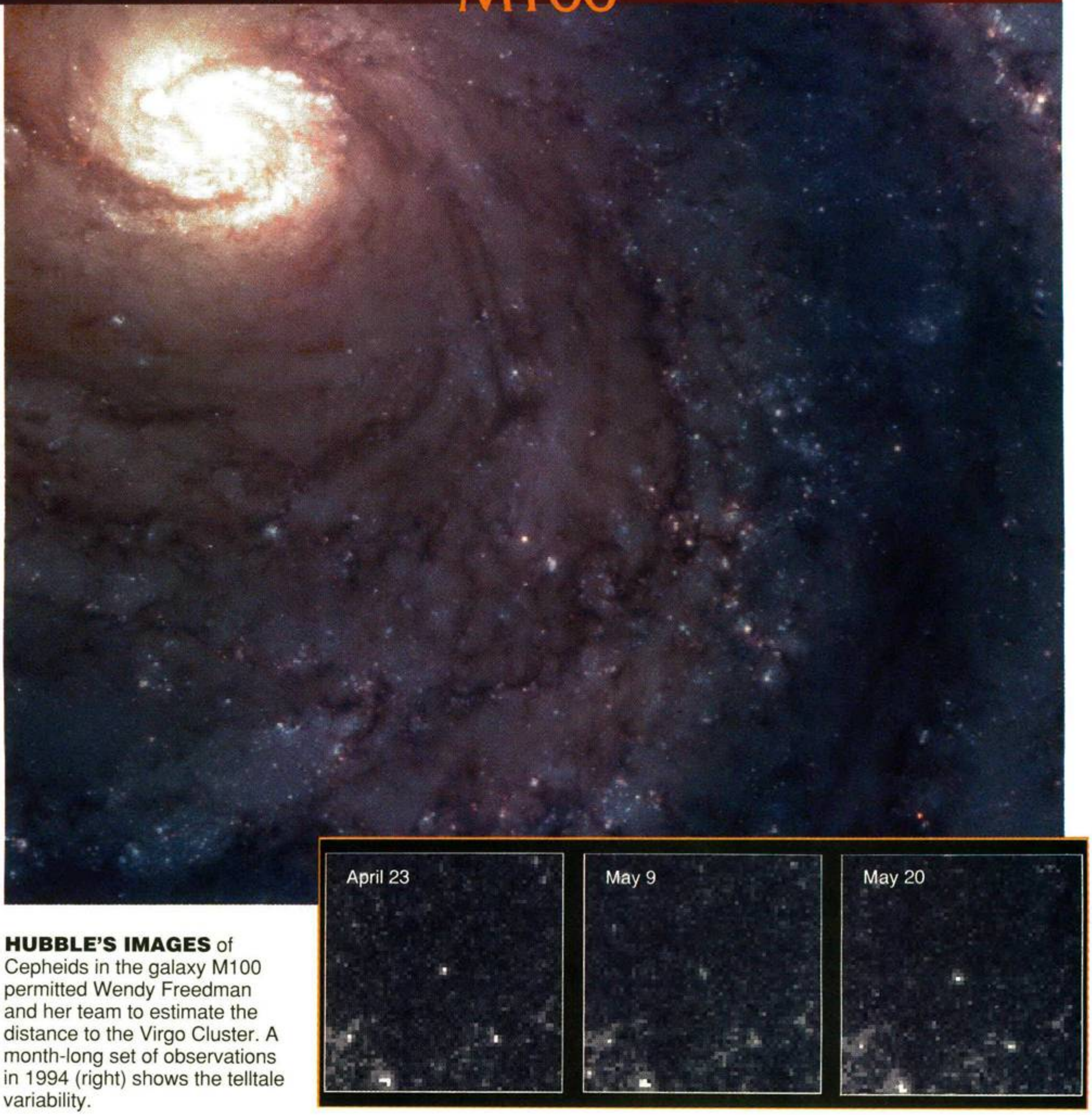
Such high values for the Hubble constant imply that the universe is uncomfortably young. For example, if the Hubble constant is 80, then the universe is only 8 to 11 billion years old, much younger than its most ancient stars. That, of course, is a logical impossibility, one that troubles many astronomers.

The Old Universe Fights Back

But not everyone worries about this apparent paradox. "I hope you're not believing all the nonsense in the press," says Allan Sandage of the Carnegie Observatories. For over two decades, Sandage has maintained that the Hubble constant is 50 and the universe old, and the recent results haven't changed his mind. He has been measuring the Hubble constant longer than both Pierce and Freedman combined; in fact, when he was a graduate student, he was the observing assistant to Edwin Hubble himself.

Sandage's critique of the new work is simple: The two spiral galaxies, NGC 4571 and M100, are not in the core of the Virgo Cluster. "No spiral lies in the Virgo Cluster's core," he says. "The spirals are spread in a 15-degree diameter about the core, so the distance to any given spiral does not of and by itself tell you the distance to the core." Only the elliptical galaxies in Virgo reside near the core, he says, whereas spirals such as NGC 4571

Freedman's prime galaxy, spiral M100



NASA/HST

HUBBLE'S IMAGES of Cepheids in the galaxy M100 permitted Wendy Freedman and her team to estimate the distance to the Virgo Cluster. A month-long set of observations in 1994 (right) shows the telltale variability.

and M100 are closer to us and other spirals are farther from us.

Pierce counters that his galaxy, NGC 4571, is at the core because the galaxy has been stripped of its outer envelope of hydrogen gas. This, he says, indicates that the galaxy is passing through the hot gas in Virgo's core, which has torn off the galaxy's hydrogen envelope. But Sandage isn't convinced.

Unlike Pierce, Freedman agrees with Sandage's point that any one spiral may not share the distance of Virgo's core. "That is our biggest uncertainty," she says. "Anytime you have a sample of one, you can be unlucky." She does not assume that her galaxy is at the Virgo core but instead says it could be 20 percent nearer or farther. This is the main reason her error bar on the Hubble constant is much larger than Pierce's, even though the Hubble Space Telescope gives clearer views of Virgo's Cepheids and more precise data on their varying brightnesses.

"Ultimately," she says, "we need to measure more Virgo galaxies to reduce that uncertainty." She and her colleagues will use the Hubble Space Telescope to search for Cepheids in two other spirals in Virgo. This will yield an average that should indicate Virgo's distance more reliably.

All three astronomers, Pierce, Freedman, and Sandage, agree one galaxy lies at or near the Virgo core: M87, the giant elliptical that anchors the cluster. Unfortunately, M87 has no Cepheids because elliptical galaxies are made up of old stars, and Cepheids are young.

Like Freedman, Sandage uses the Hubble Space Telescope to search Virgo spirals for Cepheids, but his strategy differs. "We will never make the argument that the distance of a spiral galaxy in the Virgo region defines any distance to the core," he says. Instead, Sandage wants to know the distances of those spirals because they have spawned type Ia supernovae. "These are among the best standard candles we know," says Sandage. Type Ia supernovae are thought to arise from white dwarfs that swallowed gas from a companion star, exploding when they exceed the critical threshold of 1.4 solar masses. Because all the stars are the same, the explosions should peak at the same luminosity. Also, these supernovae are extremely bright, so they can be seen in galaxies that are billions of light-years distant. Thus, Sandage argues, type Ia supernovae, coupled with Cepheids, should yield a definitive value for the Hubble constant.

Before Hubble was repaired, Sandage's team detected Cepheids in two galaxies that had produced type Ia supernovae: IC 4182 in Canes Venatici and NGC 5253 in Centaurus. The Cepheid distances they measured gave an intrinsic brightness for the type Ia supernovae that, when applied to supernovae in distant galaxies, yielded a Hubble constant of only 52 ± 6. Those who reject this Hubble constant, though, argue that all type Ia supernovae are not equally luminous. So to counter this criticism, Sandage wants to detect Cepheids in other galaxies in which type Ia supernovae have erupted. If all those supernovae peaked at the same intrinsic brightness, he says, that should convince the skeptics.

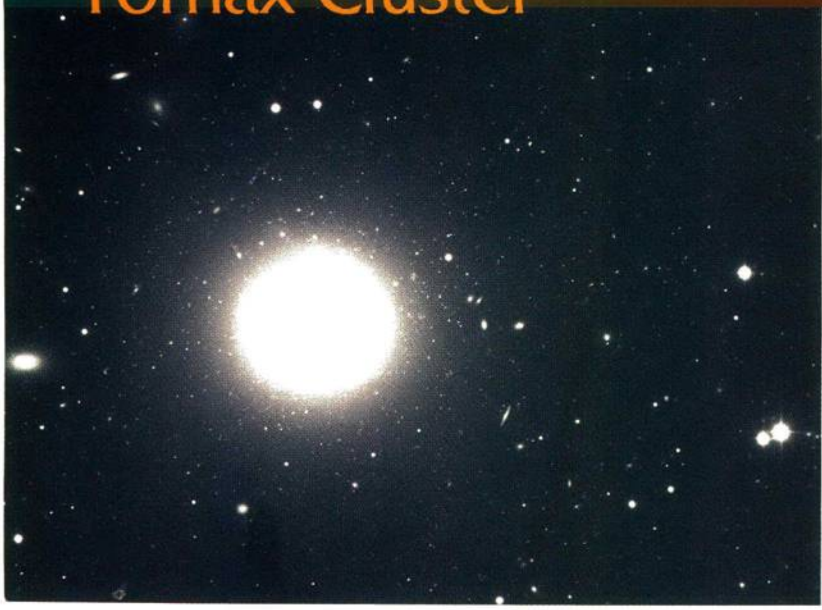
Freedman next will use the Hubble Space Telescope to detect Cepheids in a simpler galaxy cluster than Virgo. "The Fornax Cluster appears to be a fairly tight cluster," she says, "so its galaxies should all be about the same distance from us." Fornax is thought to be roughly as far as Virgo but lies in the opposite direction. These properties will give Freedman's team another example to test their method's accuracy, one that should not be handicapped by the argument that the galaxies are spread over a large area of space. Freedman's team will also observe Cepheids in other galaxies, to calibrate various distance-measuring techniques that should nail down the Hubble constant once and for all.

"I think that really is the guts of this," says Freedman. "We are now in a position to get excellent high-quality data to calibrate a number of methods. Within the next three to four years, we will have a value of the Hubble constant accurate to 10 percent. When that happens and all astronomers agree on the numerical value of the Hubble constant, one of the greatest controversies in modern astronomy — the size and age of the universe — will at last be resolved." ☐

Ken Croswell's book, The Alchemy of the Heavens: Searching for Meaning in the Milky Way, *will be published by Doubleday/Anchor in May.*

> "The controversy is not over. To say, based on three candidate Cepheids, that the controversy is over doesn't make any sense." — Wendy Freedman

The **Fornax Cluster** is Freedman's next step



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40mm Wide-Field Test, "Astronomy," Aug. 1990, p. 90

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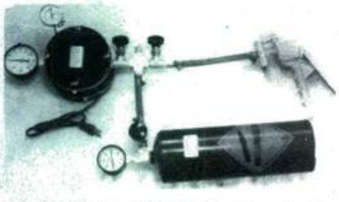

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New! Thread-on for Odyssey

FROM $69.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½'' above the telescope tube. Use the 1¼'' or 2'' versions for viewing. Use the 2'' non-rotating focuser for convenient photography with the LUMICON 2'' EASY-GUIDER™.

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2'' Astro Systems focuser, only 2'' high	**$139.00**
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Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼'' 50mm Finderscope **$59.50**, right-angle	**$59.50**
1¼'' straight-thru 80mm SUPER-FINDER	**$179.50**
1¼'' right-angle 80mm SUPER-FINDER	**$189.50**
1¼'' right-angle version, w/star diagonal	**$239.50**
25mm Cross-hair 1¼'' eyepiece (12X)	**$49.00**
Large mounting rings for 80mm Finder	**$55.00**
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1¼'' 45° diagonal for correct left-right views	**$59.50**

LOTS OF ADAPTERS

2'' adapter for C-8, Meade 2080, etc.	**$29.50**
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T-thread/1¼'' adapter	**$25.00**
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**Threaded to hold 48mm filters.*

SKY

ALMANAC

The first half of March sees a waxing Moon glide through the Winter Circle into Leo, home to dusky Mars and faint asteroid Metis. With a telescope, check out Jupiter's disappearing moon and search for an edge-on galaxy.

by Deborah Byrd

Highlights
by Jeff Kanipe

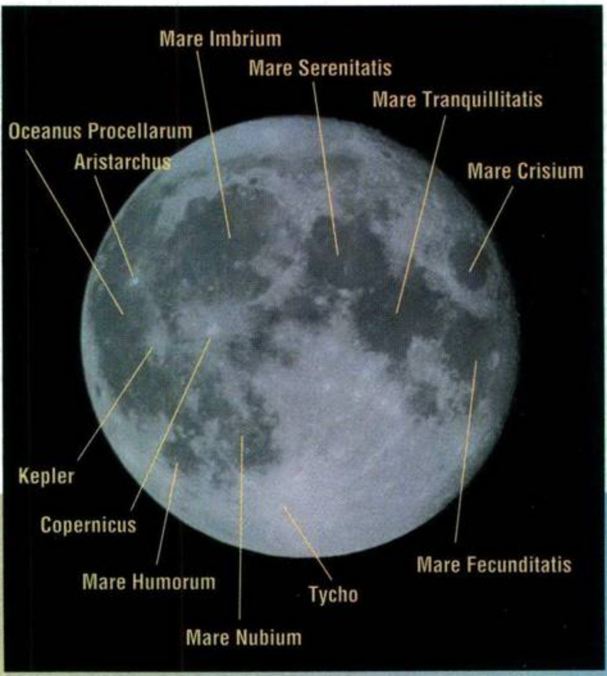
Date	Event
23	Ganymede Eclipsed by Jupiter. . . . . . . *(p. 61)*
29	Conjunction of Venus, Moon, Mercury, and Saturn . . . . *(p. 64)*
all month:	
	First Views: The Moon with Unaided Eyes. . . . . *(p. 60)*
	A Gathering in the Morning Sky . . *(p. 56)*
	The Sky's Reddest Star . . . . *(p. 63)*
	A Knife-Edge Galaxy . . . . *(p. 64)*
	Observer's Challenge: Catch the Mice *(p. 65)*
	Watch R Leonis Brighten . . . . . *(p. 63)*
	Asteroid Metis Skirts the Lion. . . . . . *(p. 64)*
	The Starry Sky: Of Snakes and Crows . . . . *(p. 61)*

As Earth moves around the Sun, the constellations we associate with winter evenings continue their westward march. In another couple of months, their distinctive shapes and asterisms will disappear into the sunset glare. Rising out of the twilight is the young Moon, which appears above the western horizon in the first days of March and spends about a week as a crescent in the west after sunset. It passes eastward through a large asterism known as the Winter Circle while waxing toward First Quarter on March 9.

The stars of the Winter Circle — made up of Orion's Rigel, Canis Major's Sirius, Canis Minor's Procyon, Gemini's Pollux and Castor, Auriga's Capella, and Taurus' Aldebaran — are some of the brightest we see from Earth. When we look toward them, we are looking in a direction opposite the center of our Milky Way Galaxy and into the spiral arm containing our Sun. In a dark, moonless sky, it's easy to trace the faint band of the winter Milky Way passing through the Winter Circle stars.

In the east and northeast during the evening hours lie two more prominent star patterns, or asterisms. One is the Big Dipper in the constellation Ursa Major, the Greater Bear. The Big Dipper ascends in the northeast on March evenings, beginning its most conspicuous time of year for evening viewing. The two stars that represent the front of the Dipper's bowl are Dubhe and Merak. Also called the Pointers, a line connecting them points to Polaris, the North Star. Follow the arc in the Big Dipper's handle to the bright star Arcturus in the constellation Bootes. Then "drive a spike" to Spica; in other words, continue your imagi-

First Views:
The Moon with Unaided Eyes



Looking for an ultimate eyesight test? Try spotting lunar detail with the naked eye.

Right after New Moon, as the Moon's phase swells into a generous crescent, you should be able to make out prominent Mare Crisium on the Moon's eastern edge, an oval dark area above the lunar equator. It is one of the few maria totally isolated from other maria.

Under Crisium and extending below the equator is angular Mare Fecunditatis, not quite as dark as Crisium but similar in diameter. As the sunrise line moves further west-northwest, the lunar dawn reveals first Mare Tranquillitatis and then, appended to it, Mare Serenitatis. At the gibbous phase, Mare Imbrium and Mare Nubium become visible.

Finally, at Full Moon a vast, gray expanse called Oceanus Procellarum comes into view, the westernmost realms of which extend practically to the limb itself. Stretching in a weblike fashion across Imbrium are three bright splash craters: Copernicus, forming the southern boundary of Mare Imbrium, Kepler to the southwest, and to the northwest, Aristarchus. Together these three craters form the apexes of an equilateral triangle.

Southeast of this triumvirate is one of the most famous craters of all: Tycho and its rays, looking to the eye like the shatter pattern in a windshield. At full phase, the ray system extends nearly a quarter of the way around the Moon.

After memorizing these lunar landmarks, challenge yourself. Try looking for more challenging craters, mountain ranges, and maria. — *Jeff Kanipe*

1995

MARCH

1 Mercury is at greatest western elongation (27°), 6 a.m. EST
New Moon is at 6:48 a.m. EST
Venus passes 1.5° north of Uranus, midnight EST

5 Saturn is in conjunction with the Sun, 9 p.m. EST

8 Moon is at apogee (242,583 miles from Earth), 10 a.m. EST

9 First Quarter Moon is at 5:14 a.m. EST

13 Mars is at aphelion (154.9 million miles), 8:34 p.m. EST
The Moon passes 9° south of Mars, 11 p.m. EST

14 Asteroid 9 Metis is at opposition (p. 64)

16 Full Moon is at 8:26 p.m. EST

18 The Moon passes 1° north of Spica, 7 p.m. EST

20 The Moon is at perigee (220,183 miles from Earth), 8 a.m. EST
R Leonis is at peak brightness (p. 63)
Vernal equinox is at 9:14 p.m. EST

22 The Moon passes 2° north of Jupiter, 9 a.m. EST

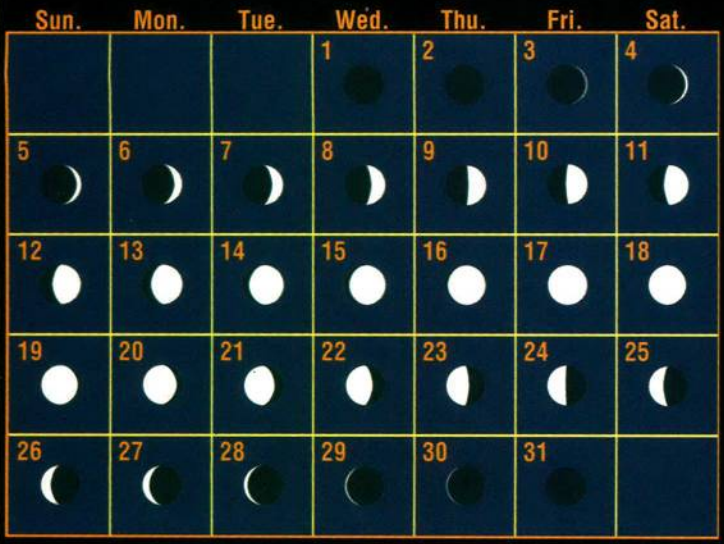
23 Last Quarter Moon is at 3:10 p.m. EST

25 Mars is stationary, noon EST
Mercury passes 0.6° south of Saturn, 7 p.m. EST

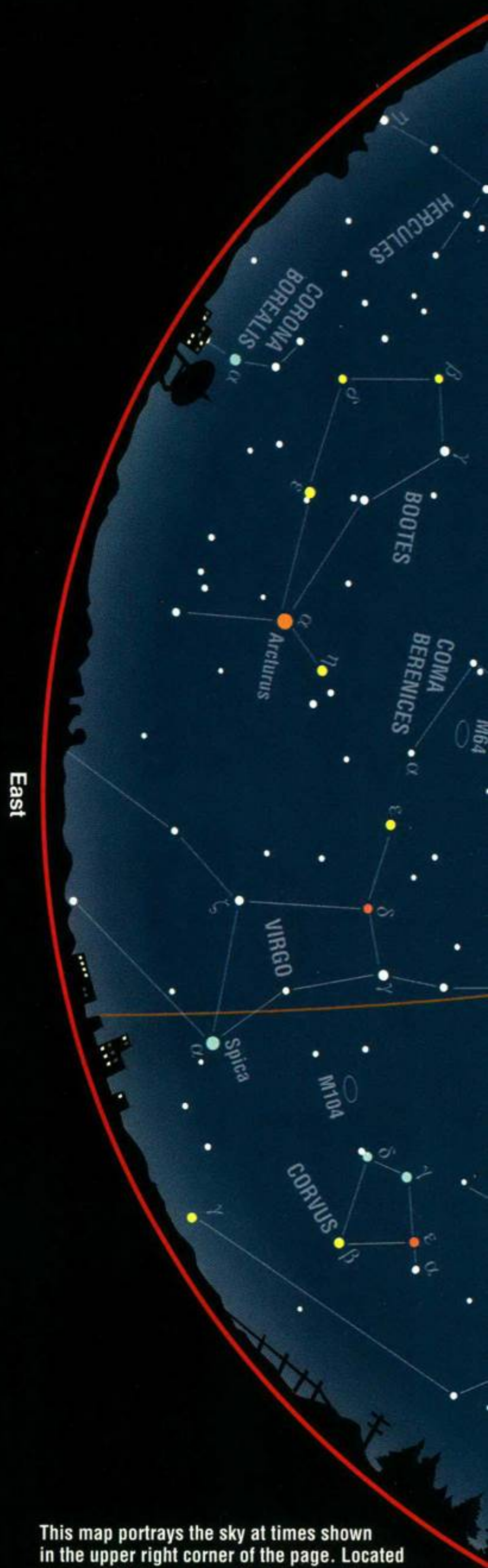
27 The Moon passes 6° north of Venus, 11 p.m. EST

29 The Moon passes 6° north of Saturn, 8 a.m. EST (p. 64)
The Moon passes 6° north of Mercury, 8 p.m. EST

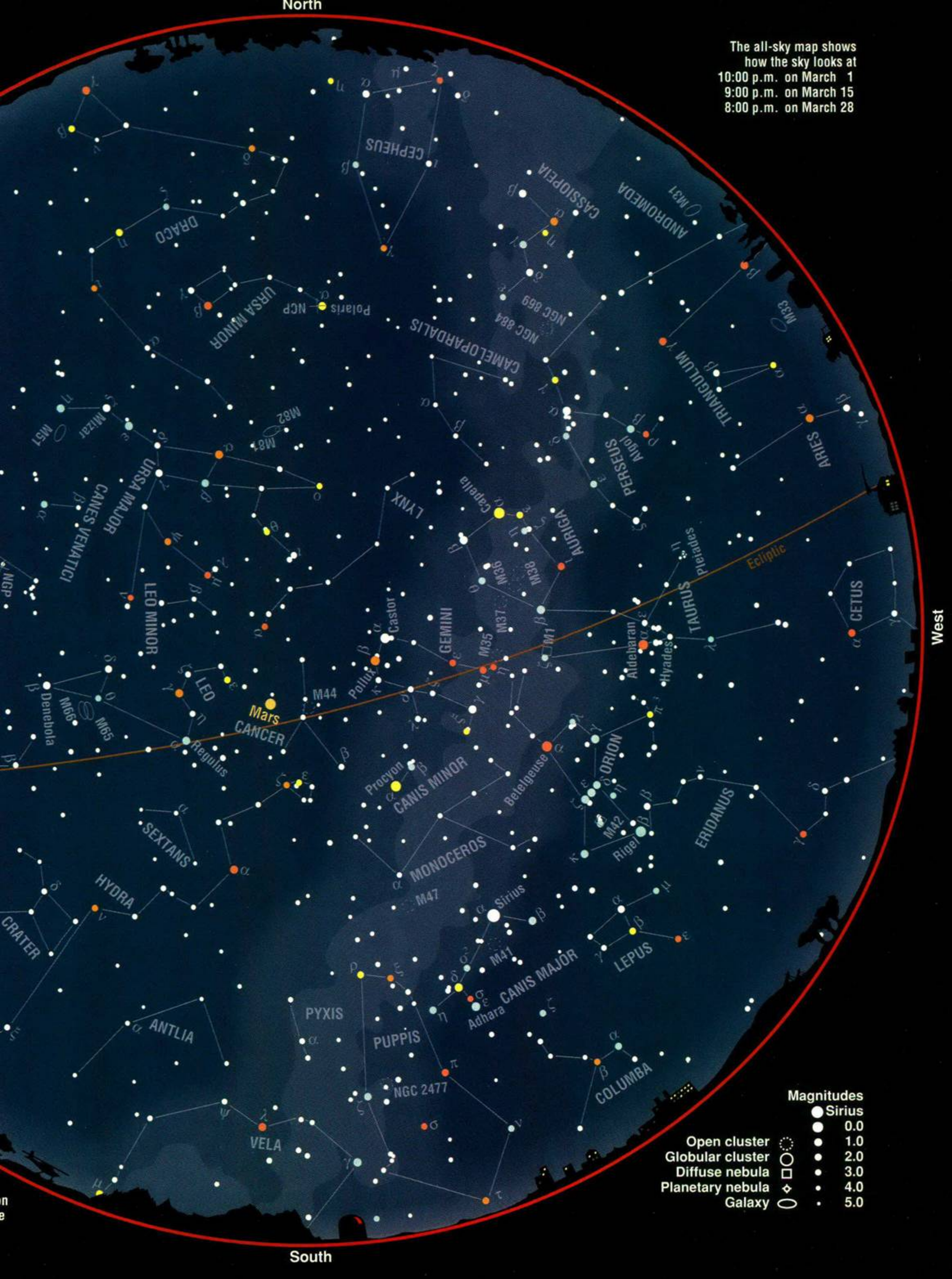
30 New Moon is at 9:09 p.m. EST



Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	



This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direct label matches the direction you're facing. The stars abo the map's horizon now match what's in the sky.


North
South
West
CEPHEUS
CASSIOPEIA
ANDROMEDA
M31
DRACO
URSA MINOR
Polaris
NCP
NGC 869
NGC 884
CAMELOPARDALIS
M33
TRIANGULUM
ARIES
PERSEUS
Algol
M57
Mizar
M82
M81
URSA MAJOR
CANES VENATICI
LYNX
Capella
AURIGA
Pleiades
TAURUS
Ecliptic
CETUS
M36
M38
NGP
LEO MINOR
Castor
GEMINI
M37
M35
M1
Aldebaran
Hyades
Denebola
M66
M65
LEO
Mars
M44
Pollux
CANCER
Regulus
Procyon
CANIS MINOR
Betelgeuse
ORION
ERIDANUS
SEXTANS
M42
Rigel
MONOCEROS
HYDRA
CRATER
M47
Sirius
LEPUS
M41
CANIS MAJOR
Adhara
PYXIS
ANTLIA
PUPPIS
COLUMBA
NGC 2477
VELA

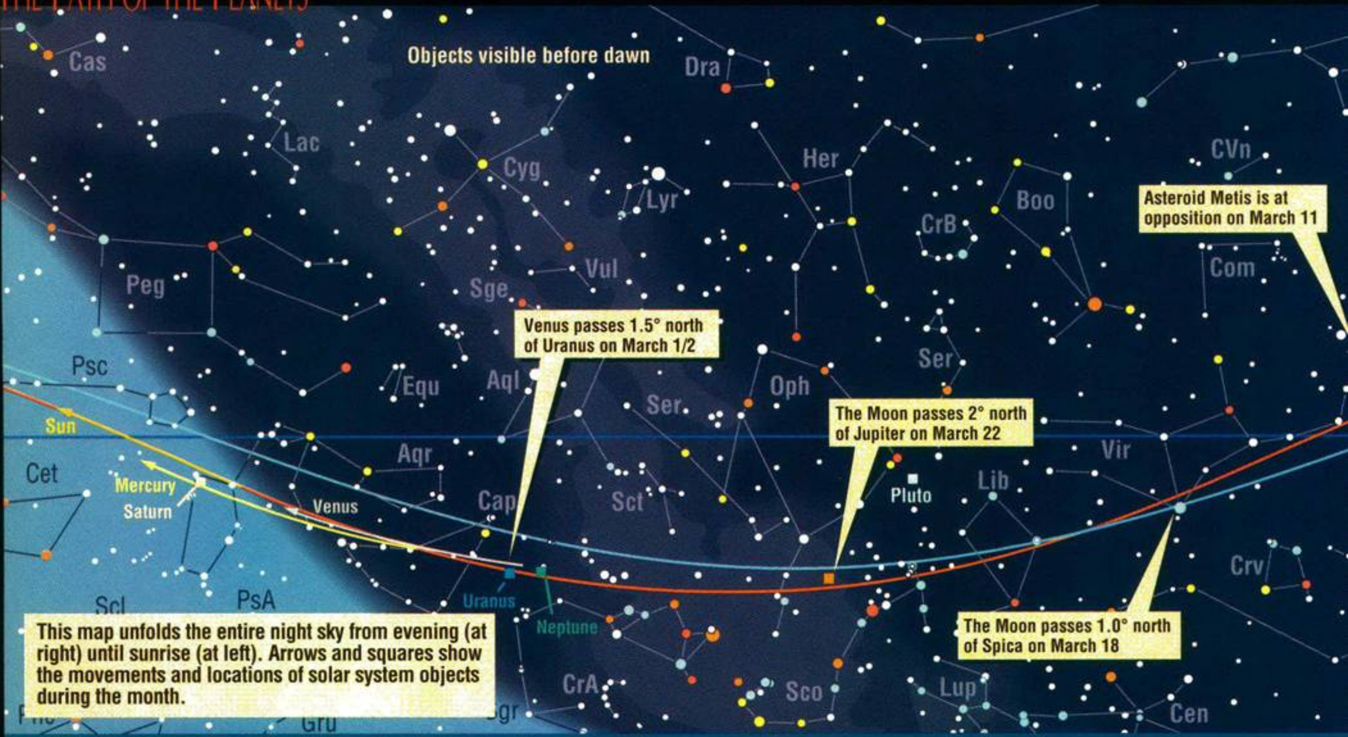
The all-sky map shows
how the sky looks at
10:00 p.m. on March 1
9:00 p.m. on March 15
8:00 p.m. on March 28

Magnitudes

⬤	Sirius
●	0.0
●	1.0
•	2.0
•	3.0
·	4.0
·	5.0

Open cluster ⁘
Globular cluster ○
Diffuse nebula □
Planetary nebula ◇
Galaxy ⬭

THE PATH OF THE PLANETS


Objects visible before dawn
Cas
Lac
Cyg
Lyr
Dra
Her
CrB
Boo
CVn
Com
Peg
Sge
Vul
Psc
Equ
Aql
Ser
Oph
Sun
Cet
Mercury
Saturn
Venus
Aqr
Cap
Sct
Pluto
Lib
Vir
Crv
Uranus
Neptune
Scl
PsA
CrA
Sco
Lup
Cen
Phe
Gru
Sgr

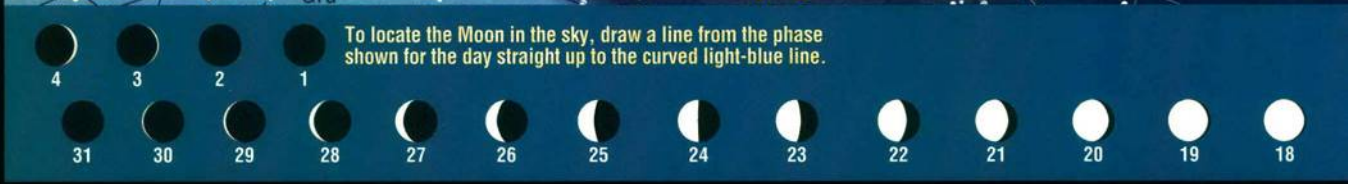
Venus passes 1.5° north of Uranus on March 1/2

The Moon passes 2° north of Jupiter on March 22

Asteroid Metis is at opposition on March 11

The Moon passes 1.0° north of Spica on March 18

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.


4
3
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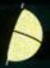
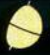
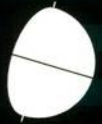
19
18

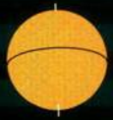
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

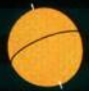
PLANETS	MERCURY	MERCURY	VENUS	MARS	MARS
Date	March 1	March 15	March 15	March 1	March 31
Magnitude	0.1	–0.1	–4.1	–0.9	–0.2
Angular Size	7.1"	5.9"	14.9"	13.2"	10.5"
Illumination	57%	75%	74%	99%	93%
Distance (AU) from Earth	0.947	1.140	1.117	0.709	0.890
Distance (AU) from Sun	0.455	0.464	0.726	1.665	1.665
Right Ascension (2000.0)	21h02.0m	22h11.9m	21h07.0m	9h22.5m	9h07.6m
Declination (2000.0)	–17°04'	–13°10'	–16°25'	19°52'	19°49'





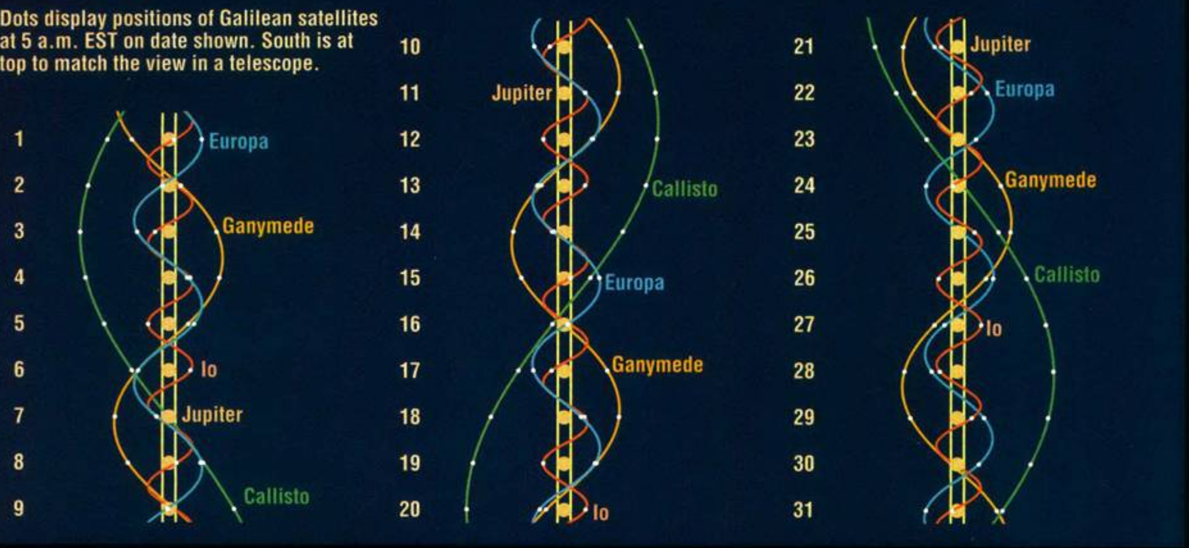


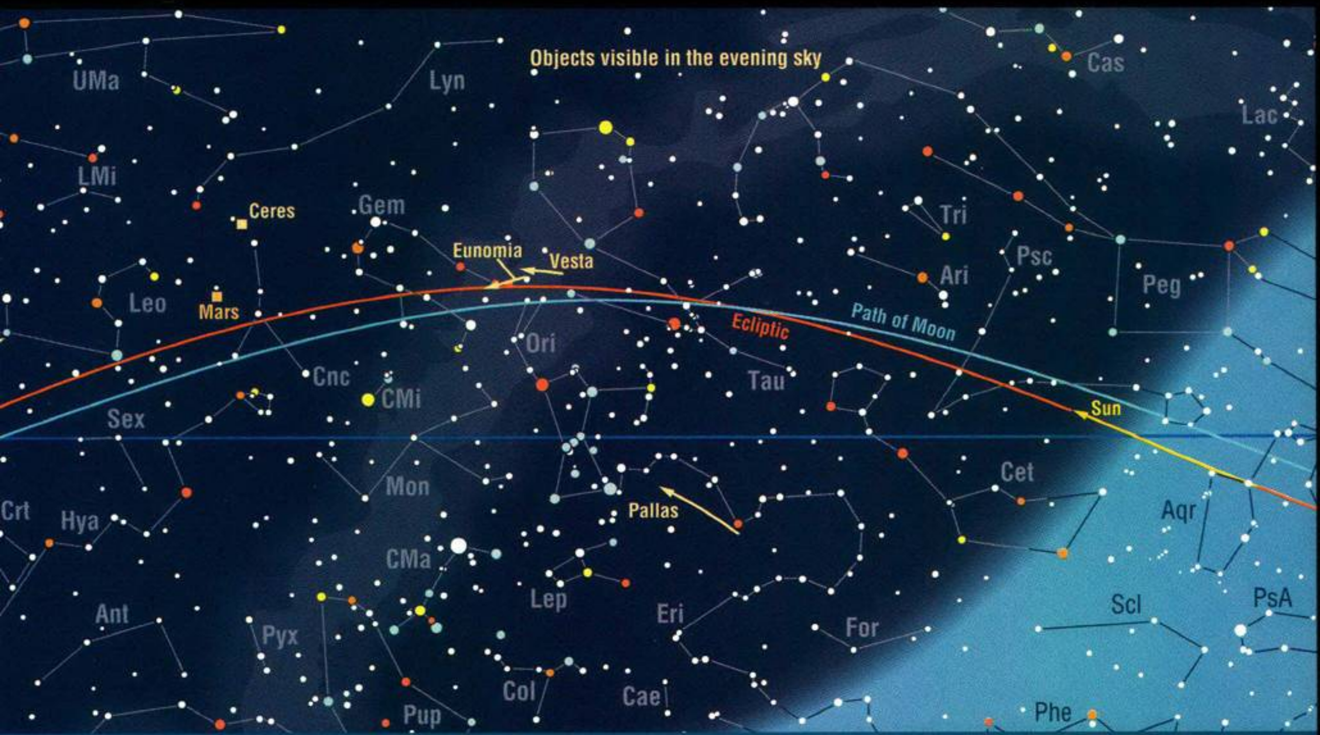




JUPITER'S MOONS

Dots display positions of Galilean satellites at 5 a.m. EST on date shown. South is at top to match the view in a telescope.




Objects visible in the evening sky
UMa
Lyn
Cas
Lac
LMi
Ceres
Gem
Tri
Eunomia
Vesta
Psc
Ari
Peg
Leo
Mars
Ecliptic
Path of Moon
Ori
Cnc
CMi
Tau
Sun
Sex
Mon
Cet
Crt
Hya
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Scl
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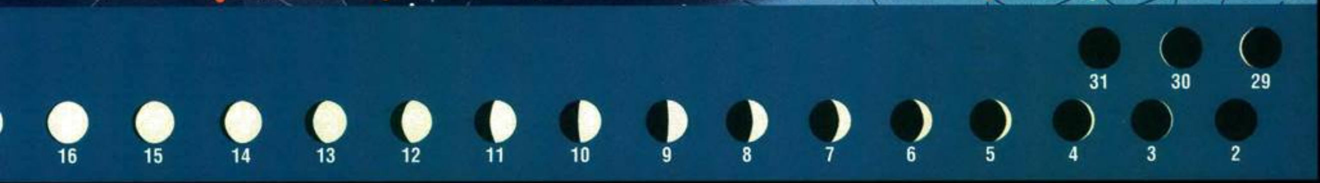
Pyx
For
Col
Cae
Pup
Phe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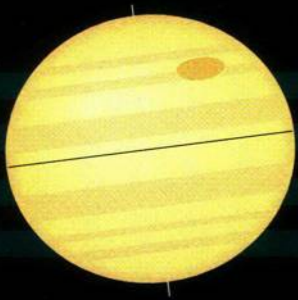
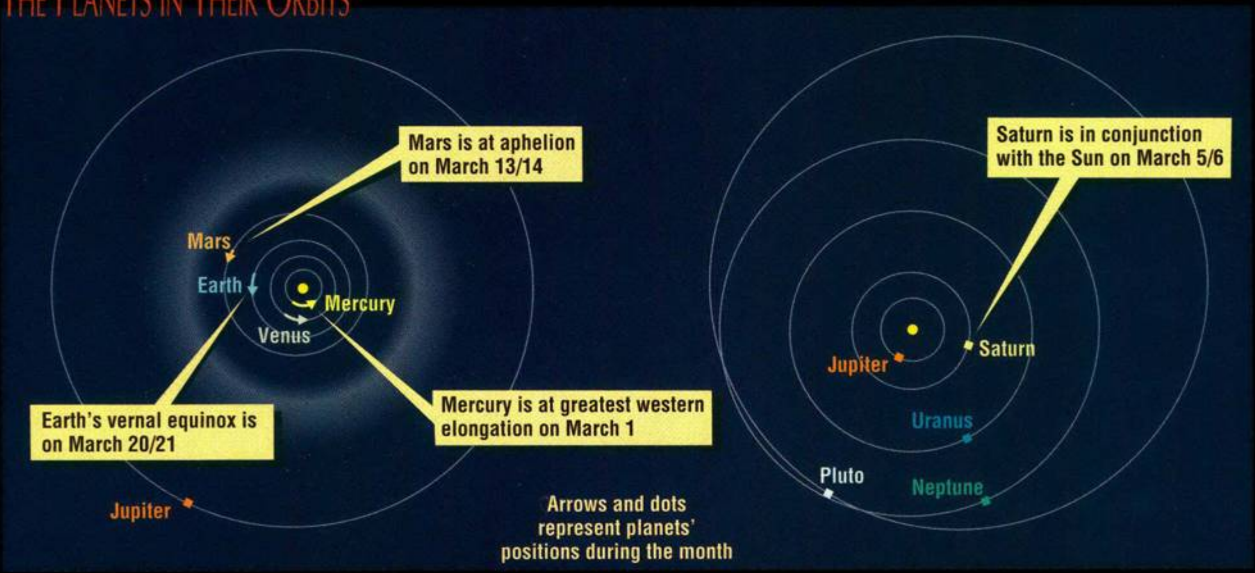


JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
March 15	March 31	March 15	March 15	March 15
−2.2	1.2	5.8	8.0	13.7
38.5"	15.6"	3.5"	2.2"	0.1"
99%	100%	100%	100%	100%
5.115	10.577	20.263	30.673	29.428
5.362	9.657	19.703	30.172	29.826
16h55.1m	23h19.0m	20h07.0m	19h47.7m	16h05.3m
−21°48'	−6°21'	−20°46'	−20°35'	−6°49'

THE PLANETS IN THEIR ORBITS


Mars
Earth
Mercury
Venus
Jupiter
Saturn
Jupiter
Uranus
Pluto
Neptune

Mars is at aphelion on March 13/14

Mercury is at greatest western elongation on March 1

Earth's vernal equinox is on March 20/21

Saturn is in conjunction with the Sun on March 5/6

Arrows and dots represent planets' positions during the month nary arc to the bright star Spica in the constellation Virgo.

The second pattern is an asterism called the Sickle in the constellation Leo, the Lion. Modern stargazers who have little experience with farm implements more readily identify this pattern with a backward question mark. The brightest star at the bottom of the question mark is Regulus, also known as Cor Leonis, the Heart of the Lion.

This year an intruder lies west of the Sickle. This object's steady light, in contrast to the twinkling stars, betrays its true nature as a planet. It's the planet next outward from Earth in orbit around the Sun: **Mars**, a windswept world of swirling red desert sands. Earth passed between this planet and the Sun last month, when Mars was at opposition to the Sun. Planets at opposition rise when the Sun sets, but of course Earth never stops moving and Mars is now well up in the east after the Sun goes down.

Because we are still fairly close to Mars — only six light-minutes away when this month begins — it now shines like a red beacon at magnitude –0.9. Look for a gibbous Moon near the planet on the night of March 13.

Mars crosses into Cancer around the middle of March. At that time, it moves in a retrograde manner, westward in front of the stars. Mars is stationary on March 25, thereafter resuming an eastward motion. It returns to Leo, to remain near Regulus later this spring.

Through a telescope Mars shows a 12"-diameter disk, still large enough to show dark areas that change from one hour to the next as Mars rotates. These changes are due to the Martian winds, which transport large quantities of light and dark dust from one region to another.

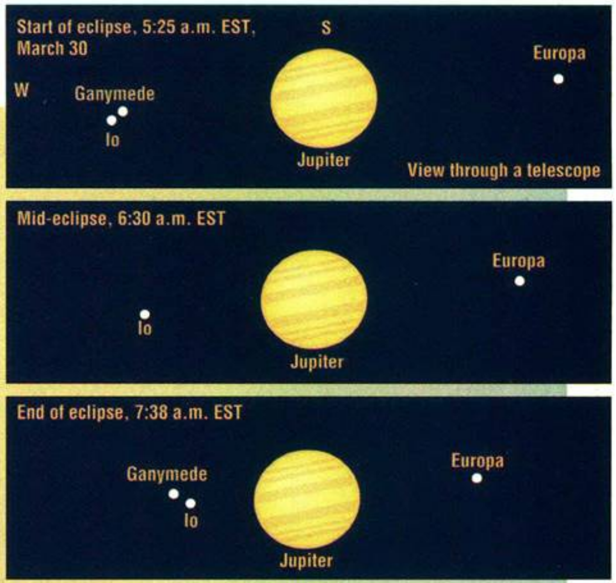
Further east in the sky is a world far beyond the relative closeness of Mars. **Pluto** ascends in the east around midnight in early March. This double world (its moon Charon is quite large compared to Pluto) is about a

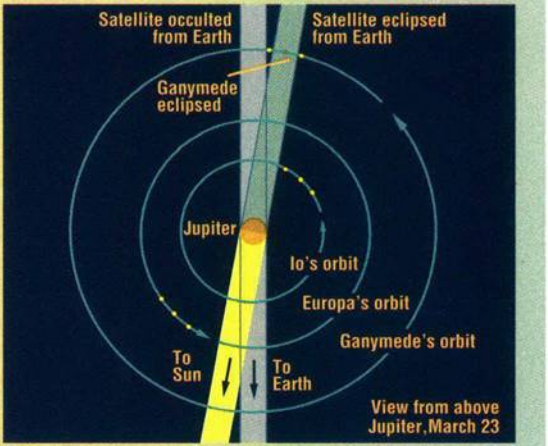
Ganymede Gets Eclipsed by Jupiter

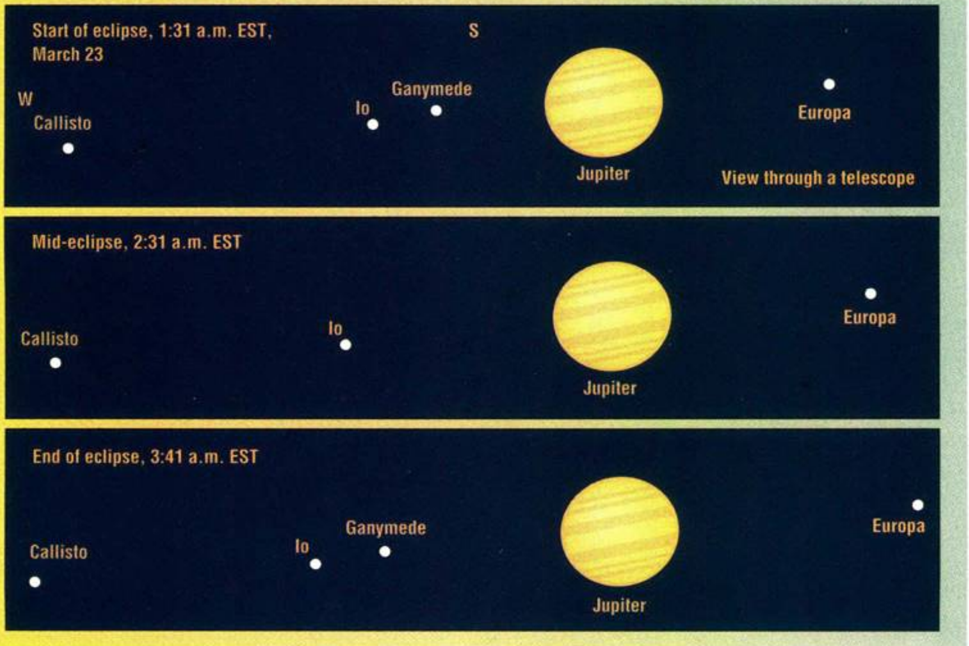
Jupiter never ceases to beguile and entertain observers with telescopes. More often than not, eyes are drawn to the dance and shadowplay of its moons. Ganymede puts on such a show this month for observers in North America by passing into and out of Jupiter's shadow. It disappears on March 23 at 1:31 a.m. EST, about an hour after Jupiter rises for observers in eastern and central time zones. All time zones witness the moon's reappearance about two hours later, at 3:41 a.m. EST.

The second eclipse happens on March 30 at 5:28 a.m. EST and is visible from all time zones. Sunrise, however, interferes with seeing the faint moon reappear at 7:38 a.m. EST for those in the eastern and central time zones. Observers in the westernmost reaches of the central time zone may want to try for this event, since the dawn sky may still be dark enough to see the magnitude 4.6 moon in a telescope, even just before sunrise.

Jupiter's equatorial diameter around the time of the eclipses is about 40". The umbra of the planet's shadow at Ganymede's distance is about 46" to 47" wide. Both eclipses occur with Ganymede northwest of Jupiter (on the Scorpius side of the disk), so be sure you're familiar with the cardinal directions in your telescope's field of view. Check out the diagrams so you know which moon is which. — *J.K.*


Start of eclipse, 5:25 a.m. EST,
March 30
S
W
Ganymede
Io
Jupiter
Europa
View through a telescope
Mid-eclipse, 6:30 a.m. EST
Io
Jupiter
Europa
End of eclipse, 7:38 a.m. EST
Ganymede
Io
Jupiter
Europa


Satellite occulted from Earth
Satellite eclipsed from Earth
Ganymede eclipsed
Jupiter
Io's orbit
Europa's orbit
Ganymede's orbit
To Sun
To Earth
View from above Jupiter, March 23


Start of eclipse, 1:31 a.m. EST,
March 23
S
W
Callisto
Io
Ganymede
Jupiter
Europa
View through a telescope
Mid-eclipse, 2:31 a.m. EST
Callisto
Io
Jupiter
Europa
End of eclipse, 3:41 a.m. EST
Callisto
Io
Ganymede
Jupiter
Europa

thousand times too faint to see with the eye, at magnitude 13.7. Even large telescopes reveal only a starry point that moves slowly this month through the constellation Scorpius. Pluto is stationary on March 6 and afterward moves in a retrograde, or westward, manner in front of the stars. We pass between it and the Sun in May.

Jupiter rises around 1:30 a.m. in early March, and by the month's end slips into the late evening sky. The giant planet is shining brightly at magnitude – 2.1 from a distance of about 43 light-minutes. We will pass between it and the Sun in early June. Though Jupiter is near Scorpius' bright star Antares, it's officially in Ophiuchus. The Moon appears near this planet on the morning of March 22.

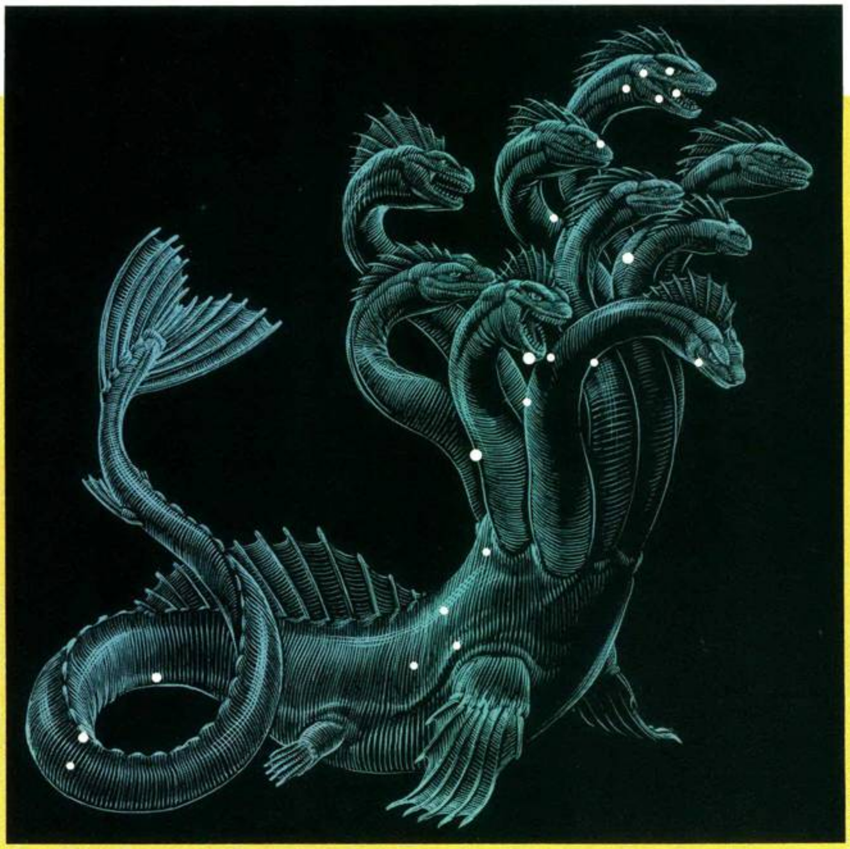
Blazing **Venus** rises a couple of hours before the Sun in early March and appears low in the southeast before dawn. At magnitude –4.1, it is the brightest object in the sky besides the Sun and Moon. Venus has two companions in the predawn sky when the month begins. **Uranus** and **Neptune** emerge from the dawn and creep up behind Venus. You will need optical aid to see them.

Mercury reaches greatest western elongation on March 1, when it is 27° west of the Sun and visible in a cloudless eastern predawn sky some 15° to the lower left of Venus. Look early in March; it disappears again before midmonth. Mercury has a conjunction with Saturn on March 25 that's difficult to see in the morning glare.

The equinox comes on March 20, marking the northward passage of the Sun across the celestial equator. At each of the year's two equinoxes, neither pole is in 24-hour darkness. The Sun bathes our whole planet in its light and warmth for half of each day.

Unless you are standing at

The Starry Sky: **Hydra**



Keith Ward

Among the many bright stars and constellations visible in the evening this month is a constellation whose claim to fame isn't prominence, but rather size. Hydra, the Water Snake, is the longest constellation. The snake's head and upper half are visible in early evening this month, but you'll have to wait until nearly midnight for the entire constellation to ascend above the eastern horizon. Hydra stretches across nearly one-third of the celestial sphere. It lies mainly south of the celestial equator and, from the Northern Hemisphere, moves across the sky from southeast to southwest.

In Greek mythology, Hydra is associated with the great snake destroyed by Hercules as one of his twelve labors. Various authors say the snake had multiple heads — sometimes 100, or 50, or as few as nine — but in each case the central head was said to be immortal. When Hercules chopped one head from the monster, two new heads grew in its place. Finally, Hercules called to his nephew, Iolaus, who brought him a number of burning torches. Then each time Hercules cut off a head, he immediately burned the stump of the neck so that no new heads could regenerate. Finally, only the immortal head was left, and Hercules buried this head beneath a rock. Before taking his leave of Hydra, Hercules supposedly dipped his arrows in the monster's toxic blood. Afterward, these arrows inflicted only mortal wounds.

In the sky, Hydra carries two smaller constellations on its back. One is Crater, the Cup, and the other is Corvus, the Crow. In one legend, the Crow used the snake to explain a bout of laziness to the Sun-god Apollo. Corvus had been sent to fetch water for the god, but lingered for some days eating fruit by the edge of a spring. He then returned to Apollo with a water snake dangling from his claws, claiming he was delayed when the snake attacked him. Apollo was not fooled, however, and he was so angry that he flung the crow, the cup, and the snake into the heavens.

The main head of the snake is a tiny grouping of five stars that ascends from the eastern horizon at this time of year, making Hydra look for all the world like a snake-charmer's cobra winding its way out of a basket. The stars of Hydra generally shine at about 3rd magnitude or fainter, and in all the snake's fabulous length it has only one somewhat brighter star.

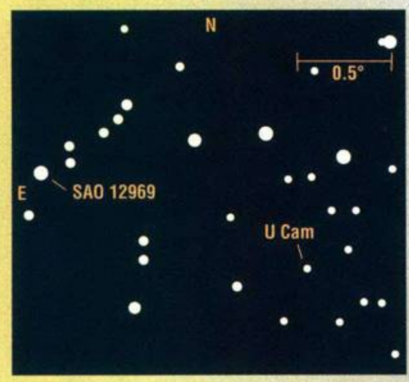
That star is 2nd-magnitude Alphard, a yellow giant star located about 100 light-years from Earth. Telescopes turned on Alphard reveal that there is a 10th-magnitude bluish star nearby, an optical companion with no true gravitational connection to Alphard.

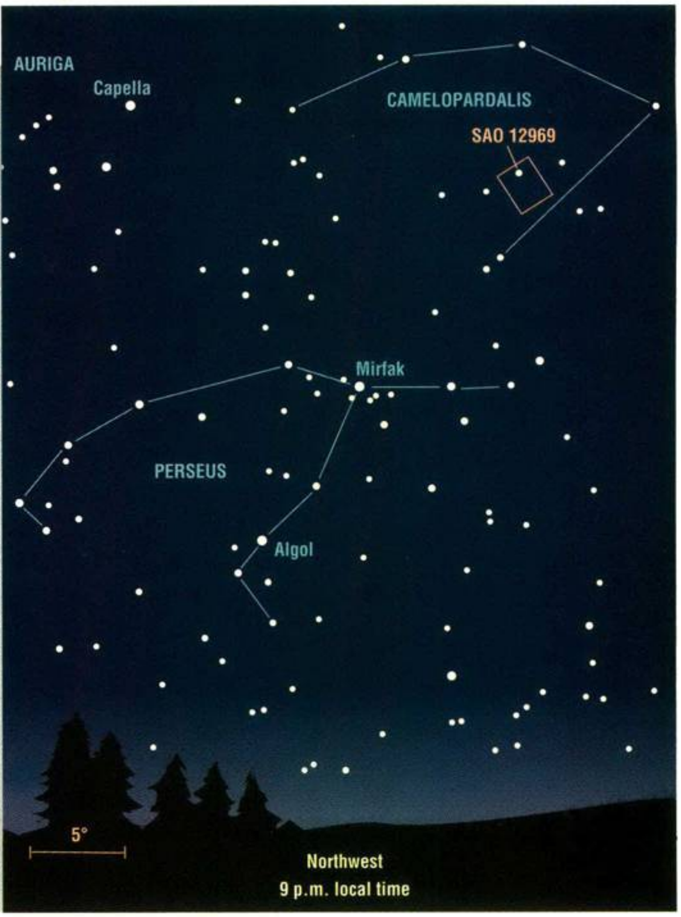
The name Alphard means "the Solitary One of the Serpent" and is sometimes said to represent the serpent's neck. Traditional stars maps, however, usually show this star as marking the heart of a large serpent or sea snake. Thus Alphard is also called Cor Hydrae, the Heart of the Water Snake. — *Deborah Byrd*

The Sky's Reddest Star

U Camelopardalis is one of the reddest stars in the sky. A spectral type of N5 puts it in the red end of the spectrum and makes it a carbon star — a red giant or supergiant with a low temperature and an excessive amount of carbon relative to oxygen in its atmosphere. Estimates put the star's distance at between 1,600 and 1,700 light-years. Like most carbon stars, it is losing mass on the order of 0.00006 of a solar mass per year.

Look for U Cam in the eastern reaches of Camelopardalis, about 15° northwest of the Double Cluster. To find it, use binoculars or a low-power telescope to star-hop 12.5° due north of Mirfak, the brightest star in Perseus. Look for a 2° arc of four stars ranging in magnitude from 4 to 6, just to the west of 5th magnitude SAO 12969. Once you have found this little group, center the easternmost star in the string in your telescope's field of view and then shift 1° due south to where U Cam shines a striking red. Once you've found it, watch the star's fluctuate in brightness between magnitude 7.7 and 9.5 over its 412-day cycle. — *J.K.*


N
0.5°
E
SAO 12969
U Cam

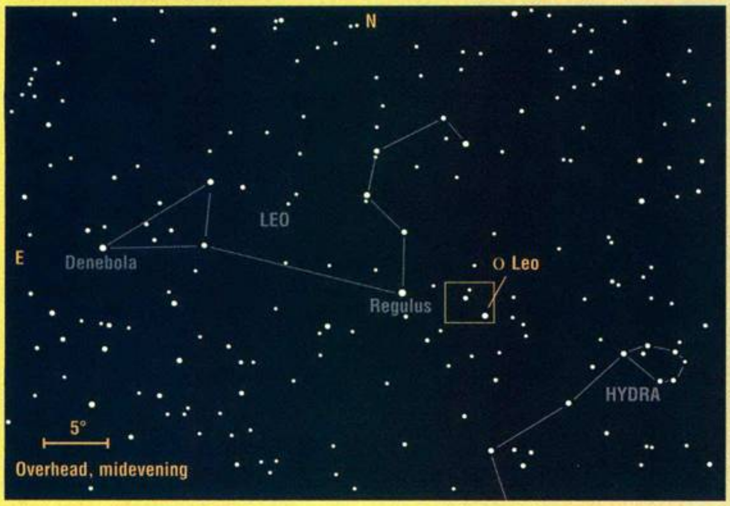

AURIGA
Capella
CAMELOPARDALIS
SAO 12969
Mirfak
PERSEUS
Algol
5°
Northwest
9 p.m. local time

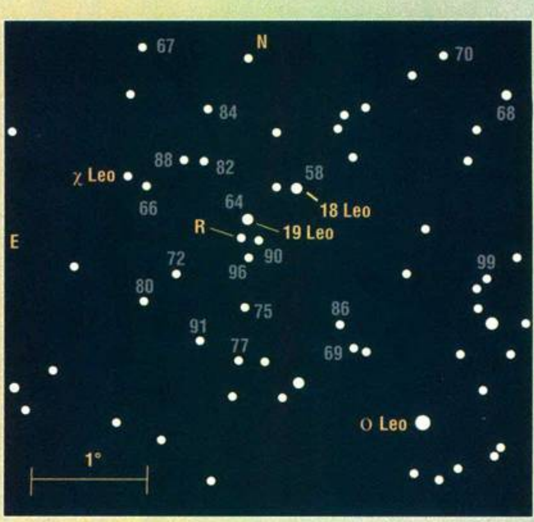
Watch R Leonis Brighten

Many veteran observers are familiar with the star Mira in Cetus. Mira is the prototype for a class of stars called Mira stars or Omicron (o) Ceti variables, a subclass of long-period variables with periods ranging from 80 to 600 days. Mira stars are red giants or supergiants that, because of their luminosity, can be seen over large distances. Many can be seen with the unaided eye at maximum light.

One such star in the spring sky is R Leonis, located 4° west-southwest of Regulus. On the average R Leonis reaches maximum brightness every 312 days. This month, if your sky is not too light polluted, R Leonis is visible to the naked eye. On or around March 20 it peaks at about magnitude 4.4, thereafter beginning a long, slow decline to a predicted magnitude of 11.3 before increasing to a new maximum next January.

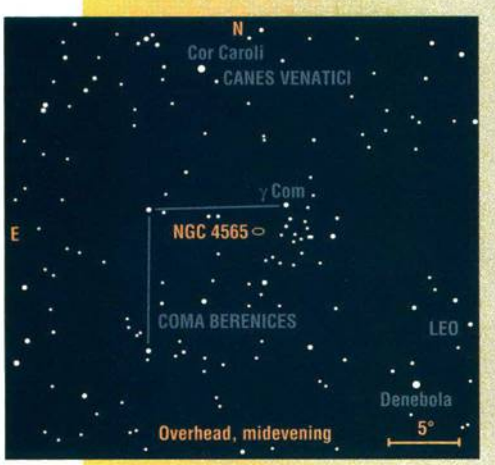
Next to R Leonis are two 6th-magnitude stars easily visible in binoculars: 18 and 19 Leonis. At peak brightness the variable gets almost as bright as Omicron (o) Leonis, which marks the foreleg of Leo. Numbers on the detailed map are magnitude values with decimal points removed. — *J.K.*


N
E
Denebola
LEO
Regulus
o Leo
HYDRA
5°
Overhead, midevening


67
N
70
84
68
88
82
χ Leo
58
66
64
18 Leo
R
19 Leo
E
72
90
99
96
80
75
86
91
77
69
o Leo
1°

NGC 4565: A Knife-Edge Galaxy

Timothy Printy

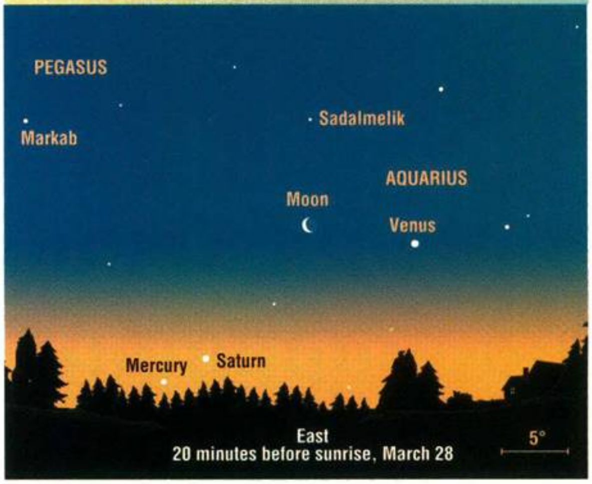


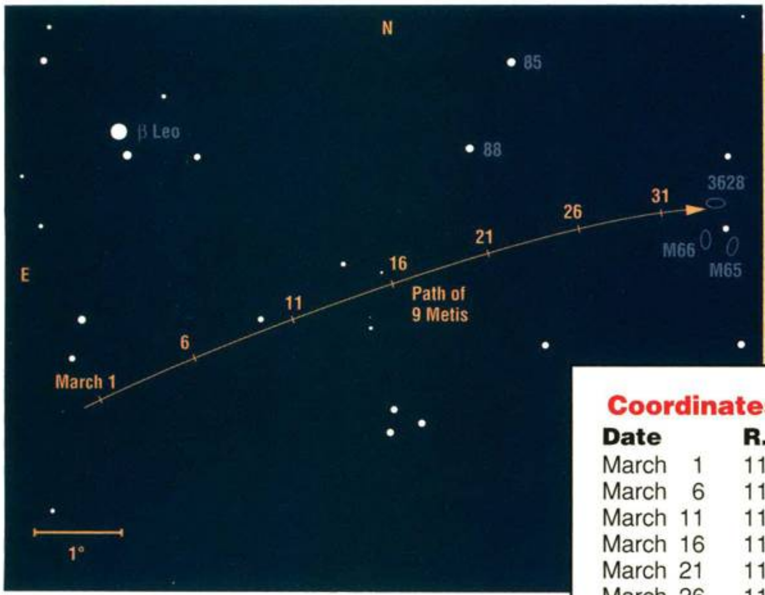
One of the spring sky's preeminent spiral galaxies, a must-see, is the edge-on galaxy NGC 4565 in Coma Berenices. To find it, center on Gamma (γ) Comae Berenices and then shift your field of view southeastward about 3°. With a magnitude of 10.4, it's easy to see in an 8-inch telescope at moderate magnification. NGC 4565 looks pencil-thin with a prominent equatorial dust lane. In larger telescopes, the lane is mottled and uneven. The galactic disk extends nearly 16' in 8- to 10-inch telescopes, though larger apertures (about 13 inches) are needed to detect its full extent. Easier to observe is the bright central bulge and stellar nucleus sitting northeast of the center. — *J.K.*

A Gathering in the Morning

Mercury reaches greatest elongation March 1, rising about an hour and twenty minutes before the Sun. Early in the month Saturn is still too close to the Sun to be seen, but it is edging further away every day. Near the end of March, from about the 24th on, Saturn and Mercury rise together. On March 25 they come up only a couple of minutes apart and are together in the sky for the rest of the month.

A rare Mercury, Saturn, Moon, and Venus conjunction occurs on the morning of March 28. The old Moon stands just 11° above the horizon at 5:15 a.m. local time (sunrise is about 20 minutes later), with Venus 7.5° degrees below and to the right of it. Saturn lies below and to the left some 12.5°, a little higher than Mercury. To spot this challenging conjunction (twilight will be very bright) use binoculars and be sure your horizon is uncluttered.— *J.K.*





Asteroid Metis Skirts the Lion

The minor planet to watch in March is the 100-mile-diameter asteroid 9 Metis. All month, it appears as a 9th-magnitude "star" moving south of Leo's hindquarters. On March 1, the asteroid is a few degrees due south of Denebola. It reaches opposition on the 14th, when it peaks at magnitude 9.2. At that time, it is a few degrees southwest of Denebola and climbing toward the northwest. By month's end, Metis lies a couple of degrees southeast of Theta Leonis, just northeast of M65 and M66.

Using a telescope, keep track of Metis' motion by sketching all the stars you see in the target area. Come back a night or two later and compare your sketch with the stars you see. The one that has moved with respect to the others is Metis. — *J.K.*

Coordinates for Asteroid 9 Metis

Date	R.A. (2000)	Dec.	Mag.
March 1	11h 45.0m	11° 18'	9.4
March 6	11h 45.3m	11° 49'	9.3
March 11	11h 40.5m	12° 18'	9.2
March 16	11h 35.6m	12° 44'	9.3
March 21	11h 30.9m	13° 06'	9.4
March 26	11h 26.4m	13° 23'	9.6

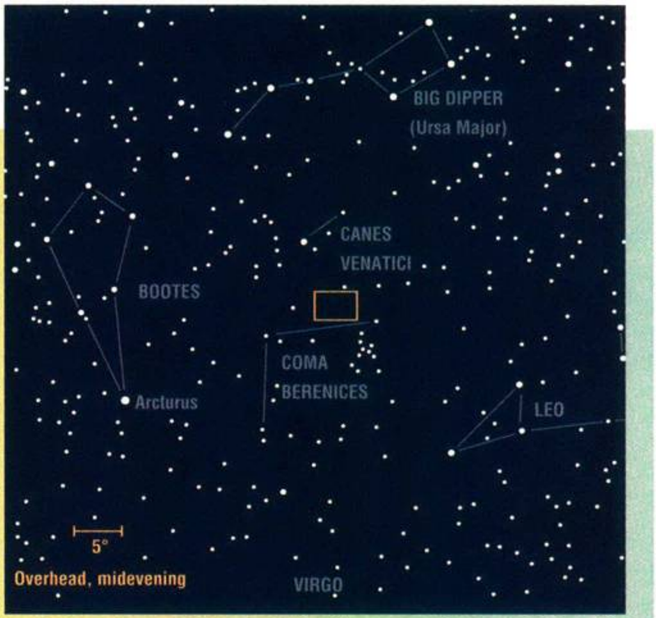
a pole, the celestial equator always intersects the horizon at points due east and due west (at the poles, the celestial equator forms the horizon line). Thus on the day of the equinox, the sunrise and sunset points mark due east and west. For fun, use a piece of tape on a window to note the Sun's location at sunrise or sunset; then watch over the coming months as the Sun's rising and setting points shift northward.

The ecliptic, or Sun's path around the sky, is distinctive at every season for the angle it makes with the eastern and western horizons in both morning and evening twilight. Around the equinoxes, the angle of the ecliptic is especially pronounced. From the Northern Hemisphere, the ecliptic stands nearly straight up with respect to the western horizon after sunset. It makes a shallow eastern angle with the horizon before dawn. Thus Mercury during this morning apparition is harder to see than it would otherwise be this month. And the steep angle of the ecliptic to the evening horizon causes a longer-than-usual time between moonrises on successive nights around this month's Full Moon. The Moon usually rises about 50 minutes later each day. On successive nights around March 16, the Full or nearly Full Moon rises more than an hour later.

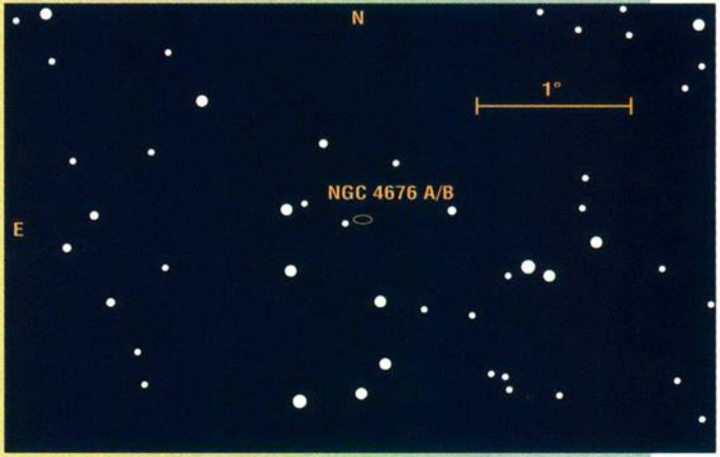
As an observing project in March, look for a very young crescent Moon. Since two New Moons occur this month, you have two chances, first on March 2 and again on March 31 (See "Spot a Young Moon," page 68). Look within half an hour after sunset, low in the west. A young Moon appears as the slimmest of crescents, as fragile against the bright twilight as any green plant now emerging to greet the spring. ☐

Deborah Byrd writes and produces the daily "Earth and Sky" radio series. Jeff Kanipe edits Star Date, *the University of Texas-McDonald Observatory magazine of astronomy.*

Observer's Challenge: Catch the Mice

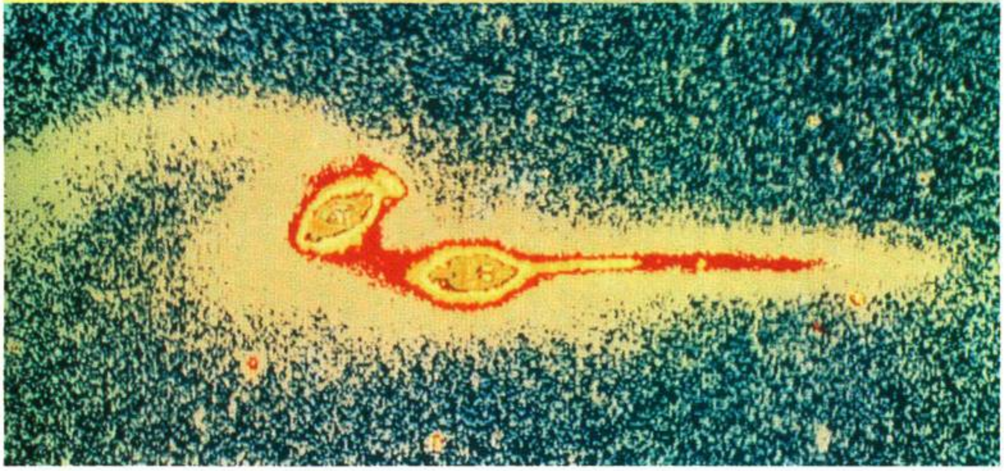


North of NGC 4565 in Coma Berenices is a classic system of colliding galaxies known as "the Mice." Catalogued as NGC 4676 A and B, the Mice consist of two merging galaxies. The gravitational effects of these galaxies on each other produces two narrow "tails" of hot gas, stars, and dust pointing in opposite directions. The duo looks like a flattened letter Z and somewhat like two mice at play.



There's just one catch to snaring detail in the Mice: You're going to need a big telescope, in the 14- to 16-inch range. (Dark skies are a must!) Each galaxy has a visual magnitude of about 13, and their apparent angular diameters are between 2' and 3', so they are small and faint. The brighter northern component, NGC 4676 A, is a peculiar lenticular galaxy (S0p); component B, to the south, is a tightly wound barred spiral, also peculiar (SBap). In a 14-inch, B appears starlike; A is definitely elongated, with a nucleus that is not as well defined as B. With averted vision, two tenuous tails can be seen trailing off in opposite directions, especially from component A. The long, straight extension from component A is easily detected in a 24-inch. The photo below uses false colors to accentuate subtle detail in both galaxies.

Theoretically, at least, 4676 A and B are visible in telescopes as small as 8 inches, but don't expect a lot of detail. To confirm their presence, look for a couple of 7th-magnitude field stars just to the south of NGC 4676 A and B. The galaxies look like two unresolved enhancements of light slightly brighter than the sky background. — *J.K.*



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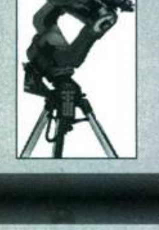

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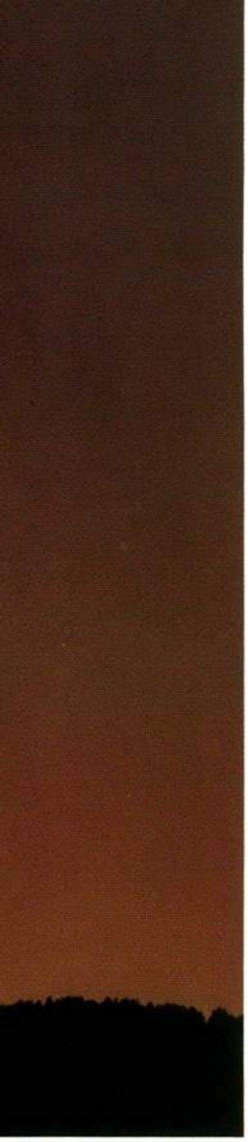
Spy the Young Moon

Take the challenge in March and find the slender crescent of a very young Moon.

by Richard Talcott

Ronald Royer



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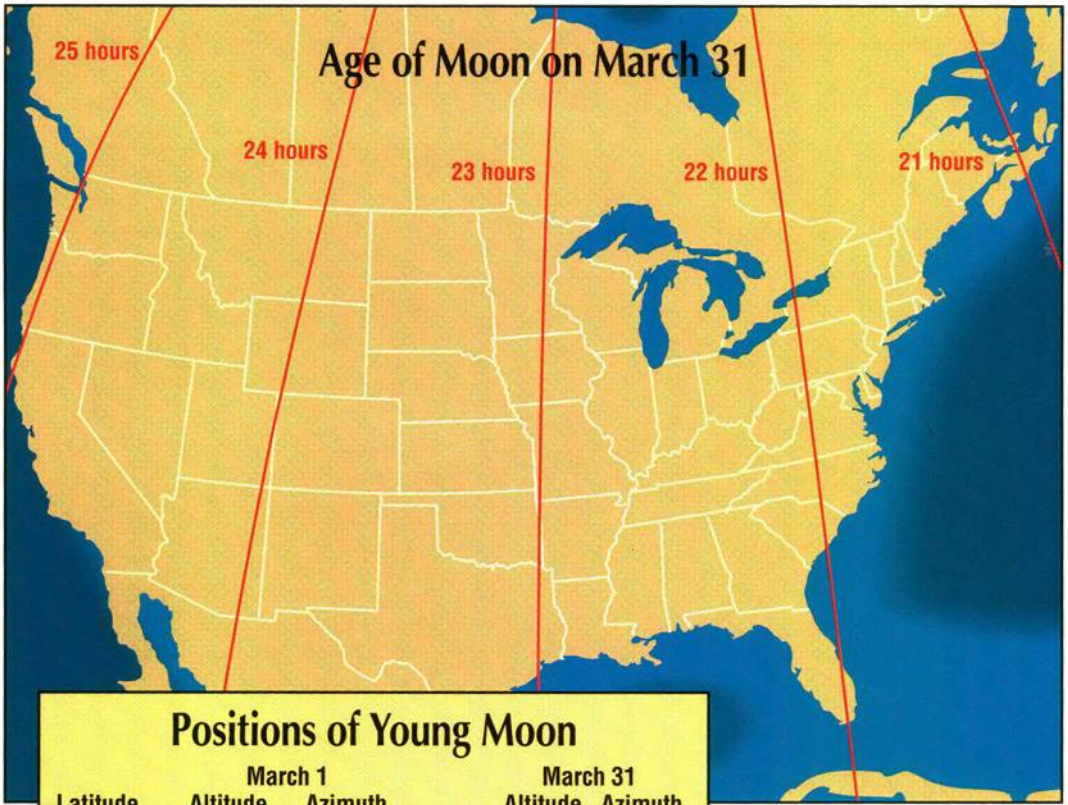


ASTRONOMY: Lee Vande Visse

Positions of Young Moon

	March 1		March 31	
Latitude	Altitude	Azimuth	Altitude	Azimuth
20°	1°	268°	6°	278°
30°	2°	267°	7°	278°
40°	3°	266°	7°	278°
50°	4°	264°	7°	278°

Positions are shown for an observer in central North America 20 minutes after the Sun sets. Azimuths are measured east from due north, so 270° marks due west.

I can remember muttering, the first time I went in pursuit of a slim moon, "Where is it? I know it's got to be around here somewhere, but I just can't . . . Wait — there it is! The Moon's silvery crescent appears so delicate against the bright twilight that I almost missed it, but in binoculars the view is breathtaking. I'll definitely have to look for a very young Moon the next time conditions are right."

Well, the time is here again: March provides us with two good opportunities to witness this stunning scene. Spotting the thin crescent depends on the time of year, the age of the Moon, and observing conditions. Early spring is the best time because the ecliptic, the apparent path of the Sun and Moon across the sky, makes a steep angle to the western horizon after sunset. Thus the angular separation of the Moon from the Sun translates mostly into altitude above the horizon.

The Moon's age measures the time since the previous New Moon, the instant when our natural satellite passes between Earth and the Sun. Seeing a one-day-old or younger Moon requires a concerted effort, though part of the fun lies in trying. The record for the youngest Moon ever glimpsed stands between 13 and 14 hours, spotting anything younger being nearly impossible because the crescent is no brighter than the twilight glare.

Conditions must be just right for spotting a very young Moon. First the Moon lies only a few degrees high, so choose an observing site that provides a clear view right down to the western horizon. The weather also must cooperate. Any haze, smog, or clouds near the horizon will have you pondering what might have been.

The first opportunity to spot a young Moon, and the more challenging of the two, comes on the evening of March 1. New Moon arrives at 6:48 a.m. EST and the Sun sets about 12 hours later, depending on latitude. That age pretty much rules out observers along the East Coast, but for those on the West Coast, the Moon will have aged three hours by the time the Sun sets, providing at least a slim chance of glimpsing it. Try scanning just a few degrees above the western horizon with binoculars 20 to 30 minutes after the Sun sets.

A better chance of seeing the young Moon comes on the evening of March 31. New Moon comes at 9:09 p.m. EST (6:09 p.m. PST) on the 30th, so eastern observers can attempt to see a 21-hour-old Moon while western viewers will have a 24-hour-old Moon brushing the horizon. (The map of North America shows the Moon's age 30 minutes after the Sun sets on the 31st.)

Once you spot the Moon with binoculars, set them aside and try to detect it with just your naked eye. It won't be easy to see, but the effort could reward you a view so inspiring you'll want to join me again next spring, squinting into the twilight glare hunting for the young Moon's slender crescent. ☐

Have You Seen the Zodiacal Light?

Among the astronomical phenomena visible to the unaided eye, the zodiacal light is perhaps the most sublime. Delicate in every respect, the zodiacal light is a uniform, soft wedge of light that stands above the horizon at the end of twilight. It is no brighter than the faintest patch of Milky Way, so you can easily see dim stars through it. The light is so elusive that its most brilliant displays are often misattributed to lingering sunset glow or light pollution from a nearby city or town. In fact, many backyard astronomers have probably seen it and didn't know it.

Despite its retiring nature, the zodiacal light is well worth hunting for, and springtime is the best season of the year to look for it in the evening sky. You might think that such a faint phenomenon would be hard to photograph, but that is easier to do than you'd think.

The Solar System's Dust Ring

The zodiacal light comes from sunlight scattering off bazillions of microscopic dust motes orbiting the Sun. The particles come from the tails of comets and from debris knocked off meteorites and asteroids by collisions. Like the planets, the dust orbits largely in the plane of the solar system, which is essentially the same as the ecliptic, the plane of Earth's orbit around the Sun as projected against the stars. The constellations through which the ecliptic path passes are known cumulatively as the zodiac, and it is from these constellations that the eerie zodiacal light got its name.

From an Earth-bound vantage point, the zodiacal light is broadest near the horizon and tapers upward as it climbs a distance of 60° or 70° above the horizon. Because the glow stretches along the ecliptic, it reaches a higher altitude and is easier to observe during the seasons when the ecliptic inclines most steeply to the horizon. Hence, in middle northern latitudes, the zodiacal light is most prominent in the west after nightfall in spring, and in the east before dawn during autumn. To see it, the Sun has to be at least 18° below the horizon. (The best seasons to view the light remain the same for observers in the Southern Hemisphere, although the actual months will be the inverse of their northern counterparts.)

That covers the mid-latitudes. In the tropics, where the ecliptic always stands more nearly perpendicular to the horizon, the zodiacal light is visible throughout the year in both the evening and morning sky. During total solar eclipses, viewers have also seen it surrounding the Sun and blending its milky glow with the soft "petals" of the Sun's corona.

The Gegenschein and Zodiacal Band

One form of zodiacal light appears in another part of the sky, where it bears a different name and is more difficult to see. Called the gegenschein (German for "counterglow"), this phenomenon appears as a very faint, elliptical glow some 10° across lying directly opposite the Sun. It is caused by dust lying beyond Earth's orbit reflecting sunlight directly back toward us in a kind of ghostly echo of the Full Moon. Because it's so faint, however, you won't see the gegenschein unless you're at a site with very dark and clear skies.

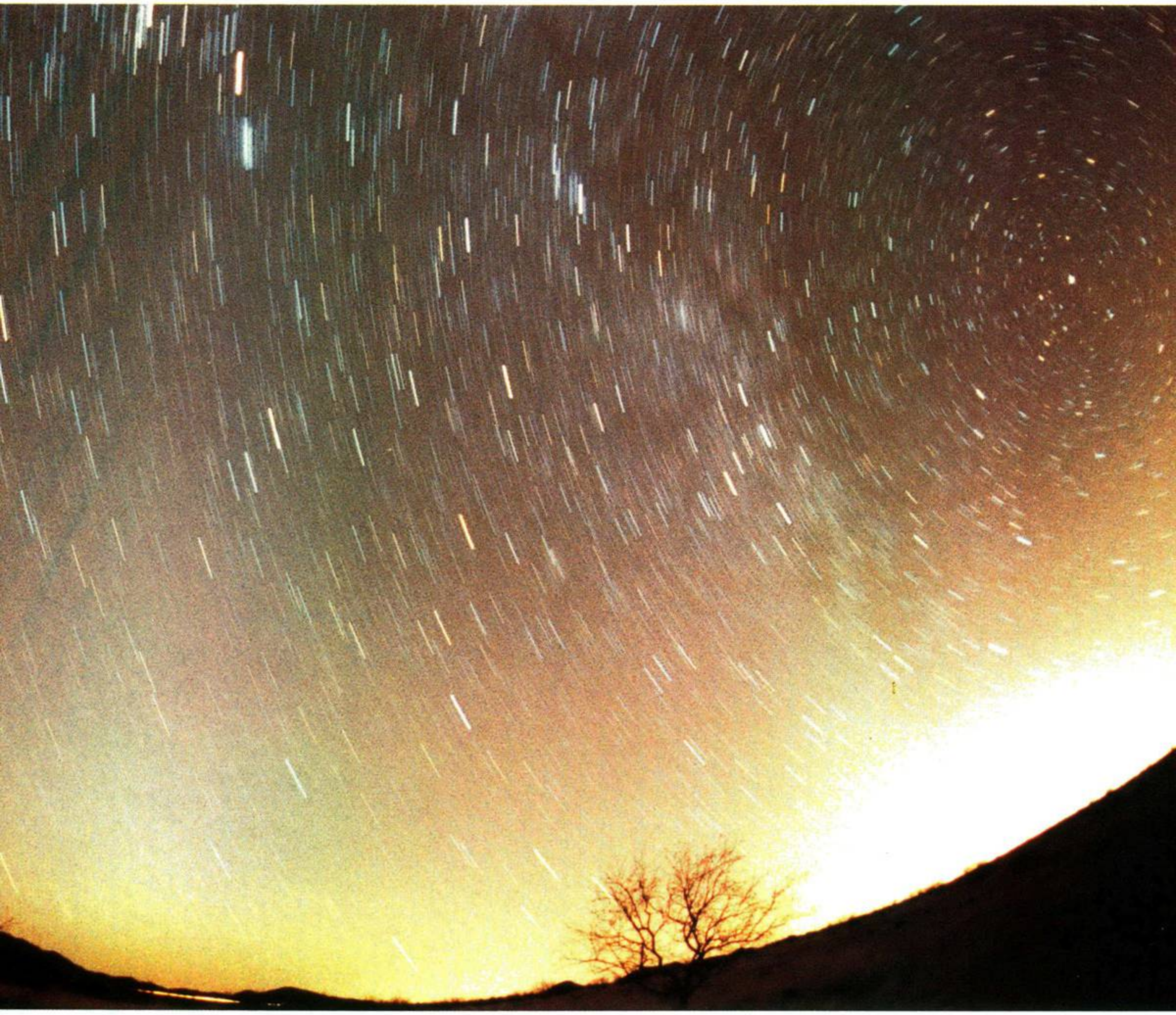
Perhaps the most favorable time to view it is during the autumn, when the glow lies projected against the relatively dull and star-poor regions of Pisces and Cetus. Still, I've clearly

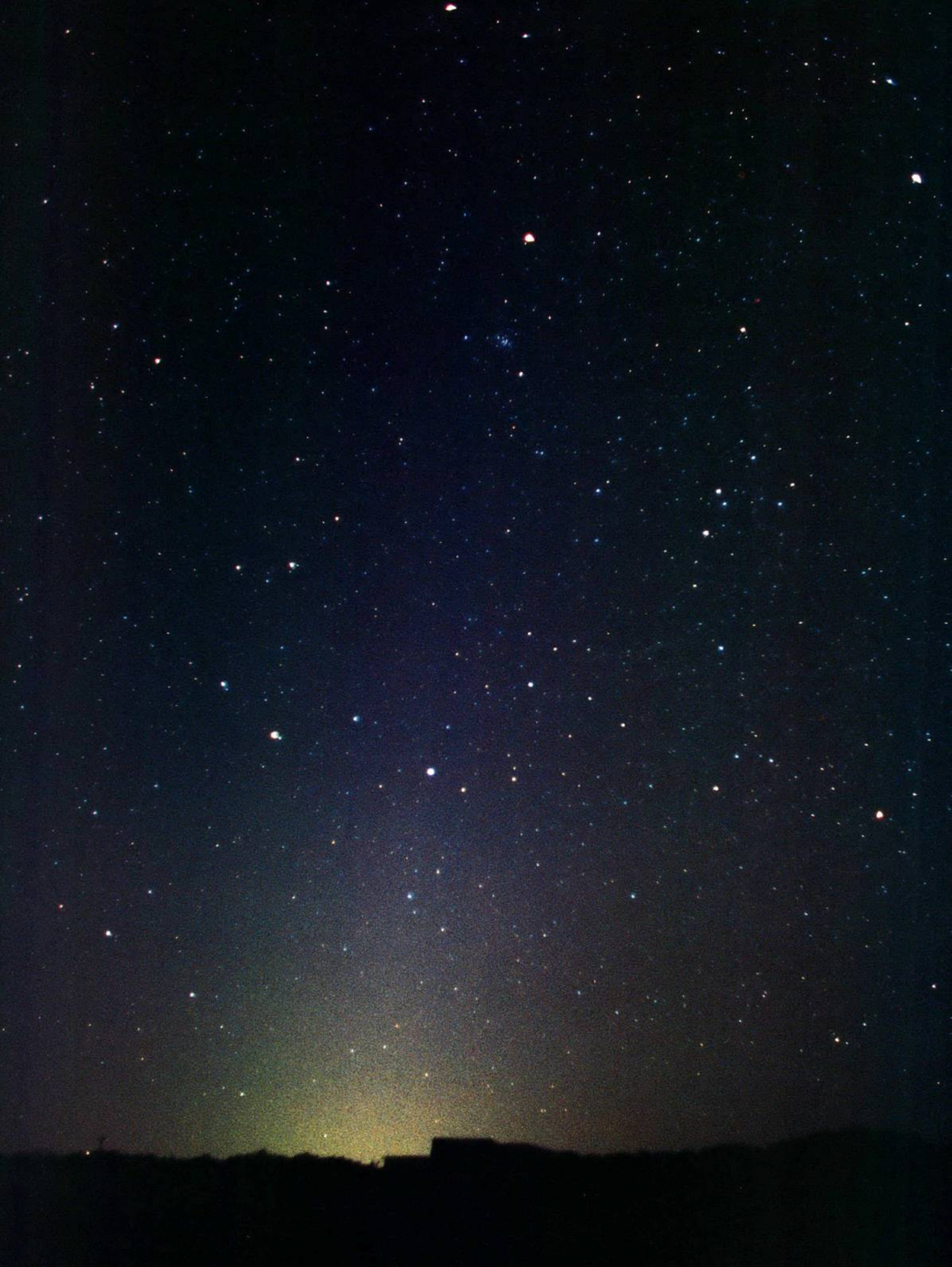
Michael Terenzoni

Spring is an ideal time to observe and photograph this elusive part of the solar system.

by Jeff Kanipe

ZODIACAL LIGHT AND MILKY WAY both appear in this super-wide-angle photo reaching from Polaris to the Hyades and beyond. Michael Terenzoni used a 16mm fish-eye lens and a 30-minute exposure at f/2.8 on Ektapress 1600 film.





seen the gegenschein from McDonald Observatory in West Texas on transparent moonless spring evenings. It was a soft patch shining among the rising stars of Leo and Virgo.

On the rarest occasions, when sky conditions are exceptionally dark and clear, you may discern a band of light connecting the zodiacal glow with the gegenschein. This light path extends along the ecliptic and is called the zodiacal band. It, like the zodiacal light and the gegenschein, results from sunlight scattering off interplanetary dust.

Tips on Observing the Light

But now it is a March evening, and the zodiacal light beckons from the west. To see it or photograph it, you're going to need dark skies and clear, haze-free conditions. An unobstructed western horizon doesn't hurt either, but if trees and other foreground objects reach no higher than about 15°, you'll be fine.

At mid-northern latitudes (30° to 35°), go out an hour and a half after sunset (two hours if you're farther north), let your eyes dark-adapt, and look off toward the west-southwest. At that time, the Sun is 18° below the horizon, which defines the end of astronomical twilight. The sky is now fully dark and all of the sunset glow should have disappeared. Look for a soft, white, wedge-shaped glow climbing up through Pisces and Aries. The wedge will lean slightly toward the south, and it would not be unusual for the glow to reach up to and beyond the Pleiades.

Don't bother with optical aid. Binoculars and telescopes are no help at all because of their constricted fields of view. You'll have to depend on your eyes alone. If the light is hard to see, try shifting your gaze across the sky very slowly. You are seeking the boundary between the cone of light and darker sky background. You may see this demarcation better if you don't look at it directly. Searching for the zodiacal light is like looking for a large, low-surface-brightness galaxy in a telescope. It's often easier to detect by looking slightly to one side of it, an old observer's trick called averted vision.

A SOFT CONE OF LIGHT, the zodiacal glow reaches up toward Cancer and the Beehive star cluster (with planetary visitor Mars nearby). This is what the zodiacal light most often looks like. Jerry Schad used a 24mm lens and a 1-minute exposure at f/1.7 on Ektachrome P1600 pushed to ISO 3200.

Photographers: Think Big and Think Faint

Photographing the zodiacal light isn't hard, but it does call for a little cleverness. The trick consists of bringing out an already ethereal luminescence against a fairly persistent, low-grade sky glow that may be tinged with the last vestiges of twilight or light pollution.

At least the equipment you need is pretty simple: a camera on a tripod, medium-speed film, and a wide-angle lens. The camera must be capable of time exposures, and you should avoid using a zoom lens unless you have no other. Zooms contain lots of glass to absorb and scatter light (which lowers contrast) and typically have photographically slow focal ratios.

With a 35mm camera, the best technique is to use a 24mm or 28mm wide-angle lens (the wider the better) and make exposures of 20 seconds to 2 minutes at f/2 on ISO 400 film. The sky must be completely dark and transparent down to the horizon to record the zodiacal light with any contrast. And even then you may have to boost the image contrast either by making several slide duplications of the original photo or by printing on high-contrast paper. Push-processing the film won't hurt, either, since it pumps up both speed and contrast.

You might shorten exposure times by using ISO 1600 or 3200 film, but this incurs a grainier image. (Fast films have less inherent contrast, too.) You won't want to use films this fast in semi-light-polluted regions because the zodiacal glow will probably disappear in the increased film grain and the scattered light from the city.

But under darker skies your options open up, especially if you piggyback the camera on a telescope with a clock drive. Try a fast film, ISO 1000 or 1600 speed, and a 50mm or 28mm lens at f/2. Position the long axis of the field of view along the ecliptic, centered about 40° above the horizon. Open the shutter for at least 5 to 8 minutes — longer if the nearest city lies more than 50 miles away. You should end up with a star-rich image, crossed by a narrow wedge of zodiacal light. If you are piggybacking the camera, any terrestrial features in the field of view — distant mountains or trees, for instance — will blur slightly, adding a dreamlike quality to the photo. Slower films with finer grain (ISO 100 or 200) also work if you're willing to extend exposures to 15 or 20 minutes. In any case, be sure you aren't shooting over any unshielded security or farm lights that may be down in the trees or just beyond the hill: That glow you capture may be a lot more local than celestial.

Twilight Times

In spring, the zodiacal light is best seen after sunset when the Sun is at least 18° below the western horizon, i.e., after astronomical twilight ends. Add the number of minutes given below to the times of sunset given in your newspaper.

Latitude:	20°	30°	40°	50°
March 1	75	80	90	110
April 1	75	80	95	115

Equipment Checklist

- ☐ Camera (must be capable of time exposures)
- ☐ Fast, wide-angle lens
- ☐ Tripod
- ☐ ISO 400 speed (or faster) film
- ☐ Cable release (to reduce vibration)
- ☐ Lens shade (to slow dewing and reduce stray light)

Taking astrophotos of extended objects — and the zodiacal light and zodiacal band are about as extended as they come! — means carefully weighing such factors as ambient light, the brightness and contrast of the zodiacal light, sky brightness and clarity, and film grain. Even how you aim your camera enters the equation. The result, though, is a kind of astrophotography that offers much more than ordinary possibilities for making expressive pictures.

Whether you try to photograph the zodiacal light or are content simply to enjoy it visually, it'll take dark clear skies and an ability to detect subtle changes in contrast. It's a quiet, low-key activity. While many observers before you have found it rewarding, it is still a branch of backyard astronomy that most observers have yet to discover. ☐

Jeff Kanipe is an amateur astronomer living in Austin, Texas. The editor of StarDate *magazine, he also writes regularly for* ASTRONOMY'S *Sky Almanac department.*

CHALLENGING PLANETARY NEBULAE

by John Franch

Wispy shells of dying stars dot the winter sky, targets for diligent observers.

Planetary nebulae show nature's approval of recycling. The nebulae are glowing balls, disks, and squirts cast off from stars in decline that litter the Milky Way Galaxy like so much stellar refuse. Like an increasing amount of refuse on Earth, the blown-out gas is headed for recycling. The material in planetary nebulae will move slowly into the interstellar medium, giving itself to new stars that will form in the future.

Tracking this subtly glowing stellar waste in your backyard scope takes you on a tour of some of the prettiest forms you can see among deep-sky objects. Blue-green starlike blobs, rings, shells, disks with Saturn-like extensions, all sorts of eerily glowing shapes await your hunting them down.

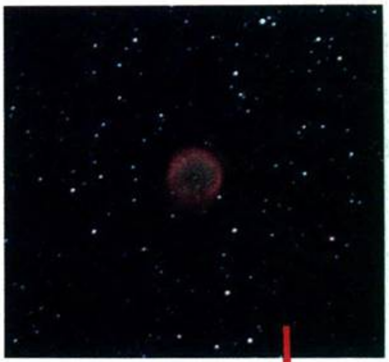
The really bright planetaries offer little challenge, so I like to go after the faint ones, the planetaries that require a keen eye and an 8-inch or 10-inch scope to see some detail. (During great seeing you can see detail in some of them with a 6-inch scope.) So get your scope, grab your best eyepieces, bring along any nebula filters you may have, and prepare for a tour of the sky's most challenging planetary nebulae. A detailed star atlas such as *Uranometria 2000.0* by Wil Tirion, Barry Rappaport, and George Lovi will show all of these objects.

If you stand outside in the early evening right now, you can see the winter Milky Way arching overhead. We'll start with the challenging planetaries of Cassiopeia, now low in the northwest, and make our way around the sky eastward, highlighting some of the most enjoyable targets for moderate-sized scopes.

Cassiopeia's bright W-shape hides a large group of faint planetaries. Start with **Hubble 12**, an object glowing faintly at magnitude 14.0 and measuring just 1" across. (The magnitudes given in this article are photographically determined. Traditional visual magnitudes are one or $1^1/_2$ magnitudes brighter.) Such a tiny object will test your eyesight and your scope's optics: In good seeing, you should be able to crank up the power and find this object about 45' southwest of the 5th-magnitude variable star AR Cassiopeiae because of its fuzzy, disklike appearance.

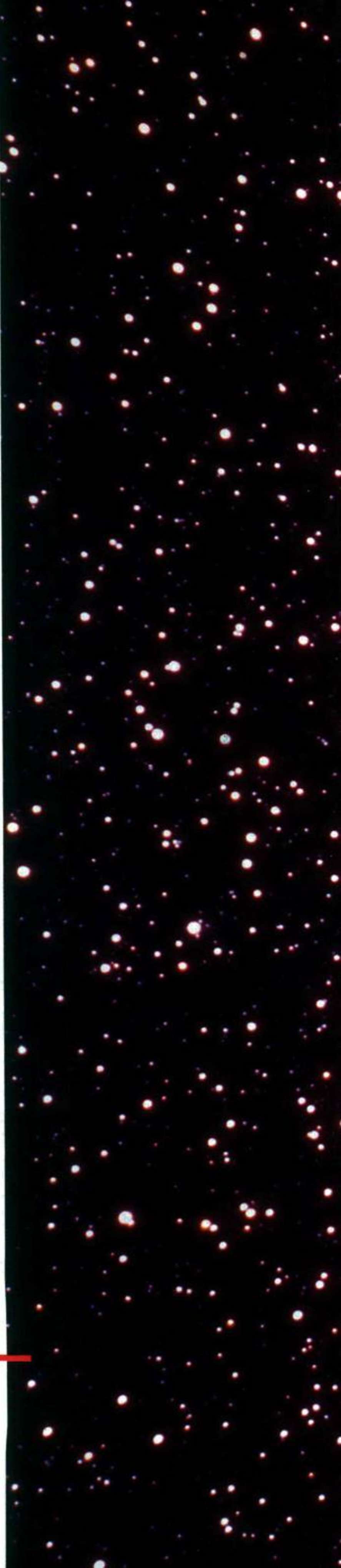
A nebula filter, particularly a UHC, Deep-Sky, or H-beta filter, placed over the eyepiece will dim the stars surrounding Hubble 12. The filter will allow the nebular light to pass through, maintaining Hubble 12's original brightness and revealing its identity. The nebula's 15th-magnitude central star is a challenge.

More varied forms of nebular



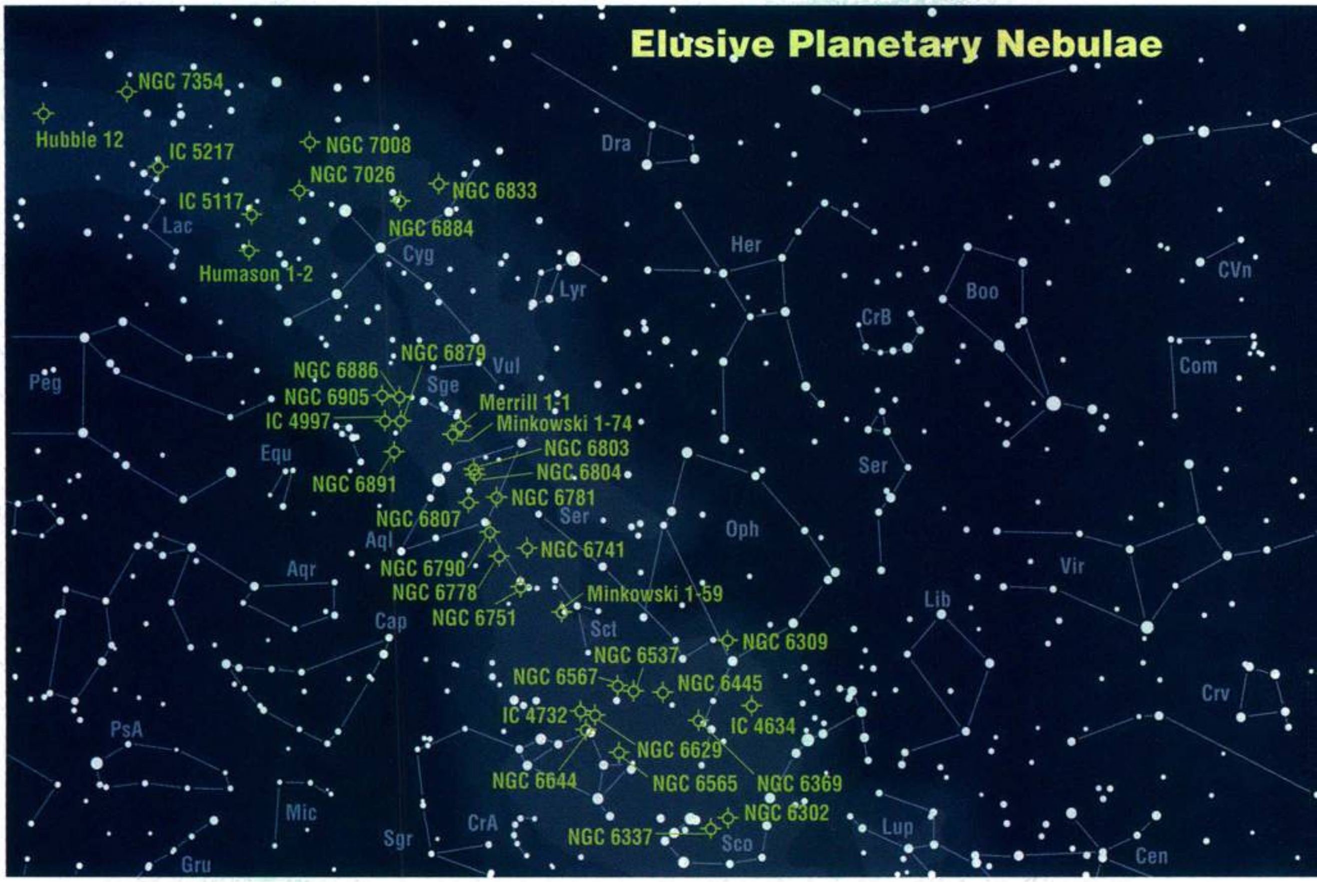
NGC 6781 in Aquila
Mag. 11.8_P
Size 109"

by Jack Newton



NGC 2438
and Open Cluster M46
Mag. 10.1_P
Size 66"

by Evered Kreimer


Elusive Planetary Nebulae
NGC 7354
Hubble 12
IC 5217
NGC 7008
NGC 7026
NGC 6833
IC 5117
Lac
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Boo
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NGC 6369
Mic
NGC 6302
CrA
NGC 6337
Sgr
Sco
Lup
Cen
Gru

structure are visible in Cassiopeia's **Humason 1-1**, **IC 1747**, and **IC 289**. A smooth disk, Humason 1-1 (mag. 13.3, size 5") lies less than 2° north-northwest of 5th-magnitude Lambda (λ) Cas. IC 1747 (mag. 13.6, size 13") is easier to find, lying just 30' southeast of 3rd-magnitude Epsilon (ε) Cas. This strange object may amuse you because of its odd appearance: At high powers the object appears as an irregular disk with traces of ringlike structure. Glimpsing the nebula's 16th-magnitude central star will not be easy. The much brighter **IC 289** (mag. 12.3, size 34") should be relatively easy to spot on a dark night. The challenge here is eyeing the inner disk and faint, outer ring that surround the nebula's 17th-magnitude central star.

Should these nebulae fail to impress you, move southeastward along the Milky Way into Perseus. Aim your scope less than a degree north-northwest of the variable star Phi (ϕ) Persei and you'll be delighted by the **Little Dumbbell Nebula** (M76, NGC 650-1), a magnitude 12.2 object covering a whopping 65". The central star glows at magnitude 16, so you won't see it without a huge backyard scope. What you will see is the object's pretty winglike structure that makes it faintly resemble a butterfly or the much larger and brighter Dumbbell Nebula in Vulpecula (hence its nickname). The dumbbell appearance is caused by a ring of dust around the star that squeezes the outrushing gas into two lobes. The Little Dumbbell is one of the most challenging objects in the famous Messier catalog of clusters, nebulae, and galaxies.

Fellow residents of the bright constellation Perseus include **IC 351** and **IC 2003**, both lying in a rich field of stars between Zeta (ζ) and Omicron (ο) Persei and the California Nebula. Seeing detail in these objects will test the most accomplished observers and the steadiest nights. IC 351 (mag. 12.4, size 7") is a little disk of gray-green light. Can you see its brightness rise slightly toward the center? The 15th-magnitude central star may be within reach of big backyard scopes. Just 2° southeast is IC 2003 (mag. 12.6, size 7") a smooth disk of even light.

Before plunging south, detour north to the vast, dim constellation Camelopardalis to see **NGC 1501** (mag. 13.3, size 52"), which lies in a barren region 1° south of the variable UV Camelopardali. This delightful object is plainly visible in any scope, but moderate magnification and a nebula filter bring out the irregular disk that will appear mottled.

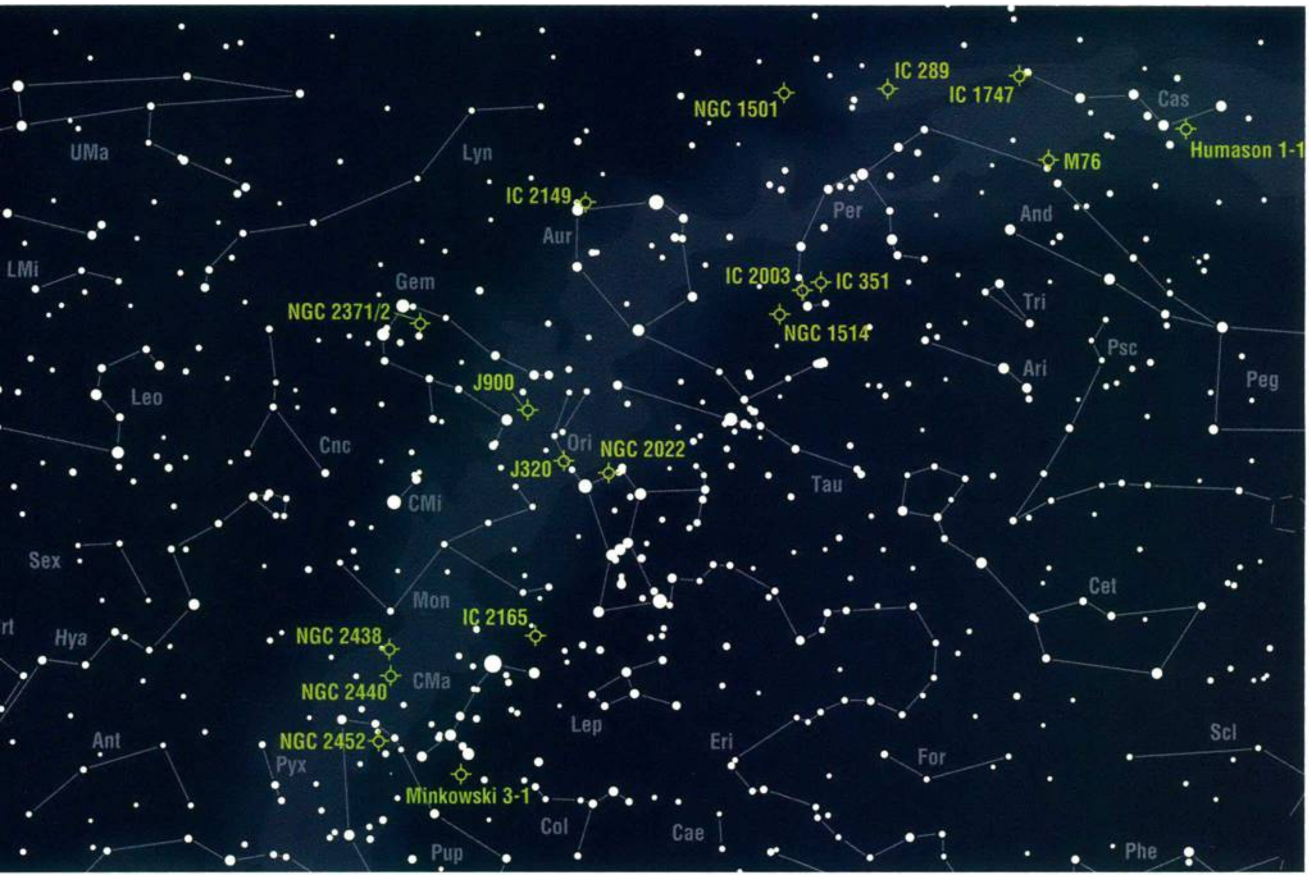
Resuming the southward journey, you may wish to visit **NGC 1514** (mag. 10.9, size 114") in Taurus the

The Little Dumbbell Nebula
Mag. 12.2$_P$
Size 65"

by Jack Newton

The Bug Nebula
Mag. 12.8$_P$
Size 50"

by Stephen Johnston
and Jim Brient


IC 289
IC 1747
NGC 1501
Cas
Humason 1-1
UMa
Lyn
M76
IC 2149
Per
And
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LMi
Gem
IC 2003
IC 351
NGC 2371/2
Tri
NGC 1514
Psc
Ari
J900
Leo
Peg
Ori
NGC 2022
Cnc
J320
Tau
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NGC 2440
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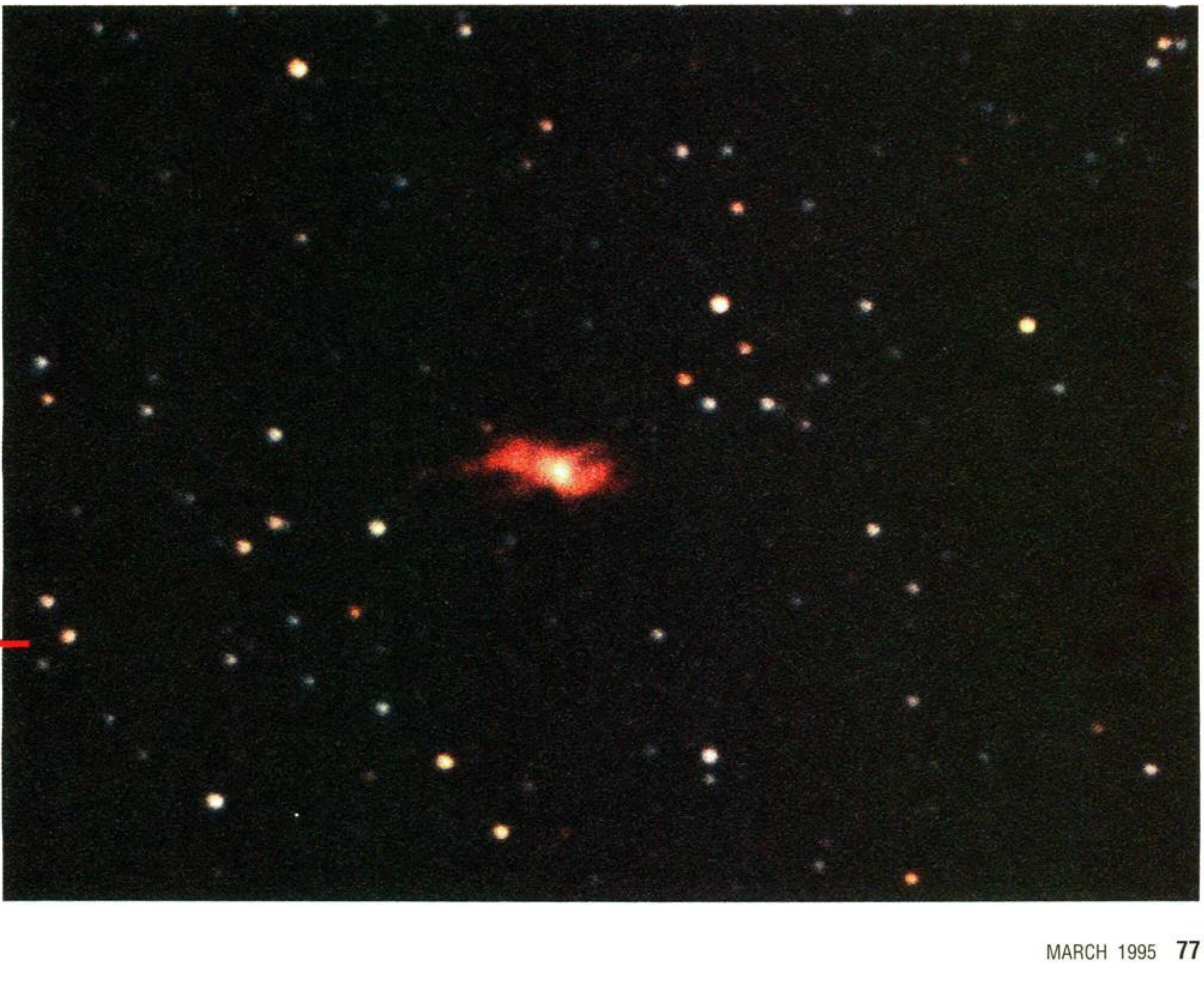
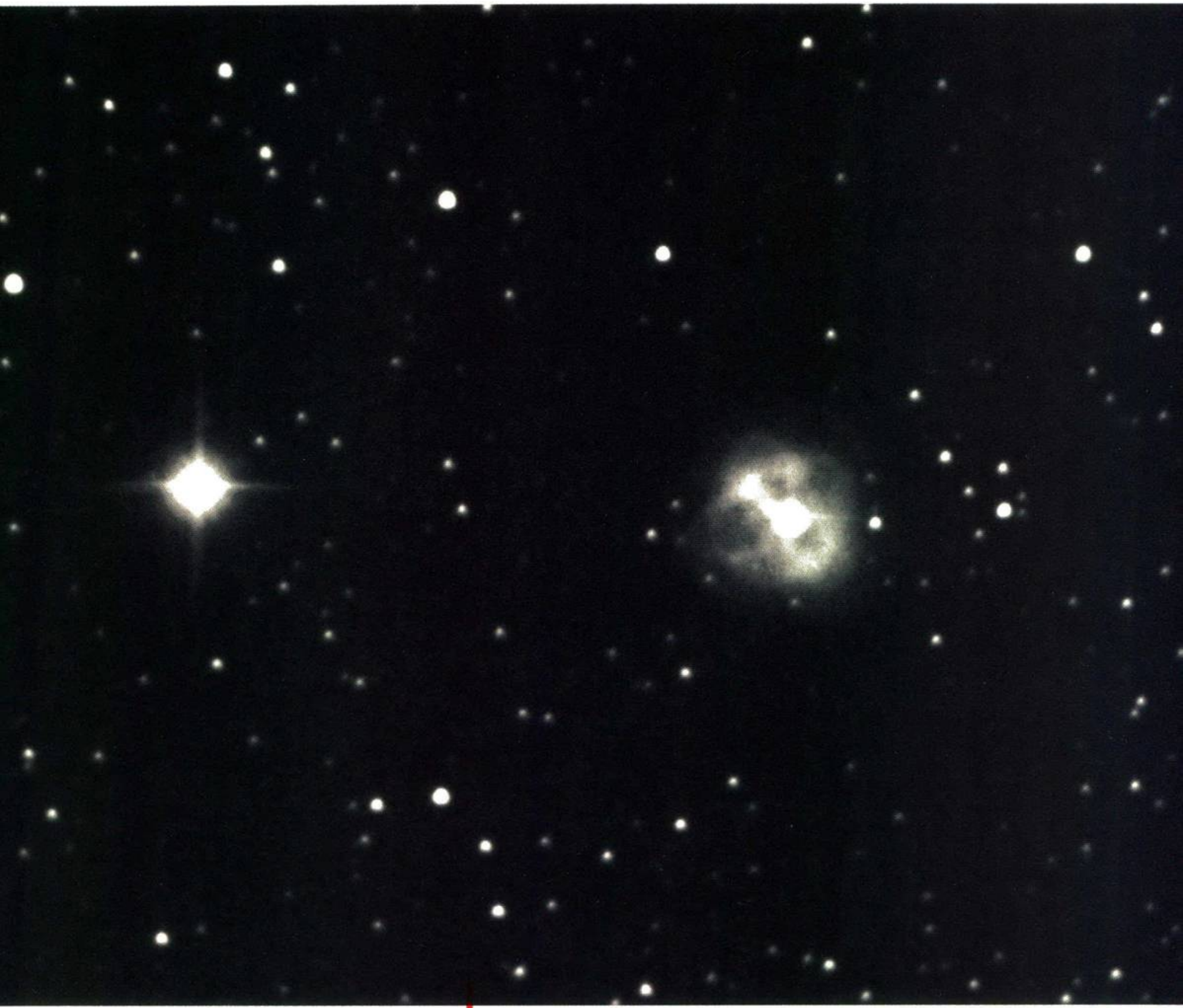
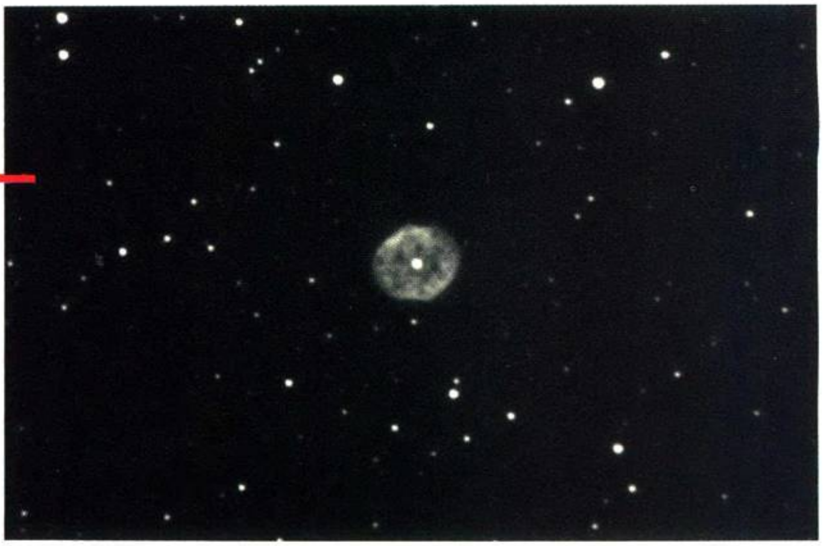
ASTRONOMY: Steven G. Davis





NGC 1514 in Taurus
Mag. 10P
Size 114"

by Martin C. Germano



NGC 1501 in Camelopardalis
Mag. 13.3P
Size 52"

by Martin C. Germano

IC 289 in Cassiopeia
Mag. 12.3$_P$
Size 34"

by Martin C. Germano

NGC 7008 in Cygnus
Mag. 13.3$_P$
Size 83"

by Martin C. Germano

Bull. This large, detailed object resides 2° north-northeast of 5th-magnitude Psi (ψ) Tauri. Those who have been disappointed by faint central stars will now get their reward. The star glows at magnitude 9.4, making it brighter than the surrounding nebula, which appears as an eerie glow composed of a blotchy, irregular disk.

Toward the east, grabbing the bull by the horns, is Auriga. Here you'll find the small, bright disk of **IC 2149** (mag. 11.2, size 8"). The nebula is remarkably easy to find because it lies just over 1° north-northwest of 2nd-magnitude Beta (β) Aurigae. Peering into the eyepiece may not immediately separate IC 2149 from the many background stars. But careful viewing at moderately high power will reveal the nebula's splotchy, ringlike disk surrounding a more uniform, inner disk of velvety light.

The stream of the Milky Way now cascades southeastward into Gemini, where two more challenging planetaries recycle. **J900** (mag. 12.4, size 8") hangs suspended in a starry field 3° northwest of the 2nd-magnitude star Gamma (γ) Geminorum. This object resembles IC 2149 but is a full magnitude fainter. Far more delightful is **NGC 2371-2** (mag. 13.0, size 55"), a big, faint nebula lying 1$^1/_2$° north of 4th-magnitude Iota (ι) Gem.

Riding along the great ghostly arc of light known as Barnard's Loop brings us to the splendid constellation Orion, a deep-sky paradise of the winter sky. Orion's **J320** and **NGC 2022** are both challenging objects for medium-sized scopes. J320 (mag. 12.9, size 7") lies 1$^1/_2$° northwest of the 5th-magnitude double star 16 Orionis. Observers with large scopes may spot the 14th-magnitude central star. NGC 2022 (mag. 12.4, size 18"), located just over 1° east of Psi^2 (ψ^2) Ori in the "shoulders" of the hunter, is much easier to separate from the background stars.

A final target for the winter Milky Way, **NGC 2438** (mag. 10.1, size 66"), lies between us and the rich star cluster M46 in Puppis. Hence, it appears to be floating inside the cluster. This beautiful pairing adds to the visual delight of NGC 2438, which looks like a distinct ring in a moderate-size scope.

Dozens more challenging planetary nebulae lie scattered across the winter and summer skies, and a few dot the stark regions of sky in spring and autumn (see map on pp. 76-77). Among the summer's greatest hits are the gorgeous glowing disk **NGC 6781** in Aquila, the flattened **Bug Nebula** (NGC 6302) in Scorpius, and the beautiful ring **NGC 6337** in Scorpius.

The wispy shells you have just explored are challenges that should encourage you to explore further. As always, ASTRONOMY wants to hear about your observations.

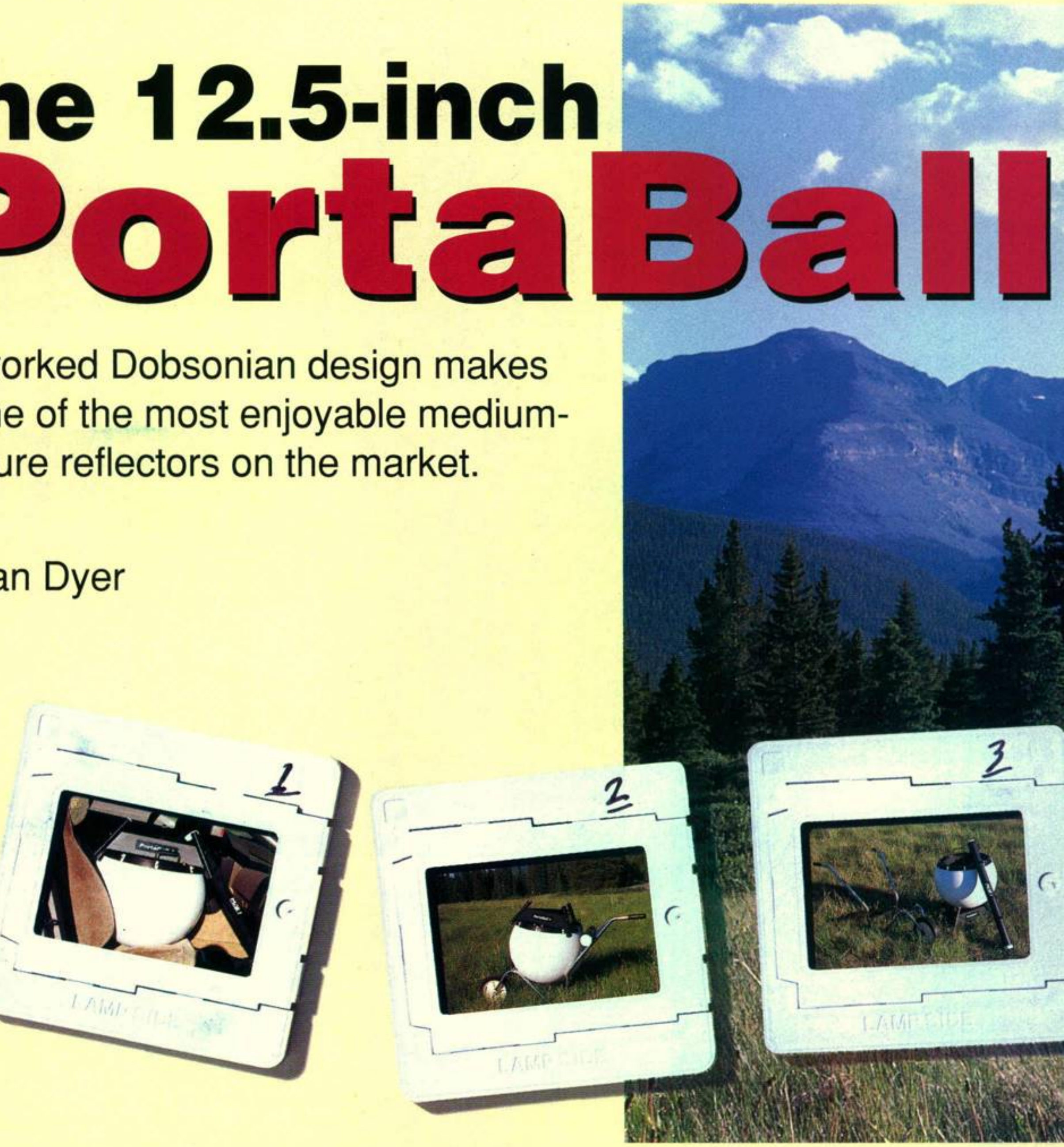
In the meantime, enjoy these winter objects. If they have invited you to observe more critically and to get your telescope out more often, then these balls of recycling gas will have opened a new window on the sky. ☐

John Franch is an enthusiastic observer who uses a 6-inch reflector from his home in Bellwood, Illinois.

The 12.5-inch PortaBall

A reworked Dobsonian design makes for one of the most enjoyable medium-aperture reflectors on the market.

by Alan Dyer



If the telescope industry had annual awards, I would nominate this reflecting scope for the innovative design category. I know what you're thinking — it looks like an overgrown Edmund AstroScan. But when I took the PortaBall out for a spin around the sky, I quickly recognized the value of its unorthodox design.

Peter Smitka, one of the Midwest's foremost telescope makers and owner of MAG1 Instruments, has created a user-friendly telescope. The PortaBall moves to any spot in the sky with an ease few telescopes can match. The eyepiece and finder are always right where they should be, with no straining, craning, or climbing required to reach them.

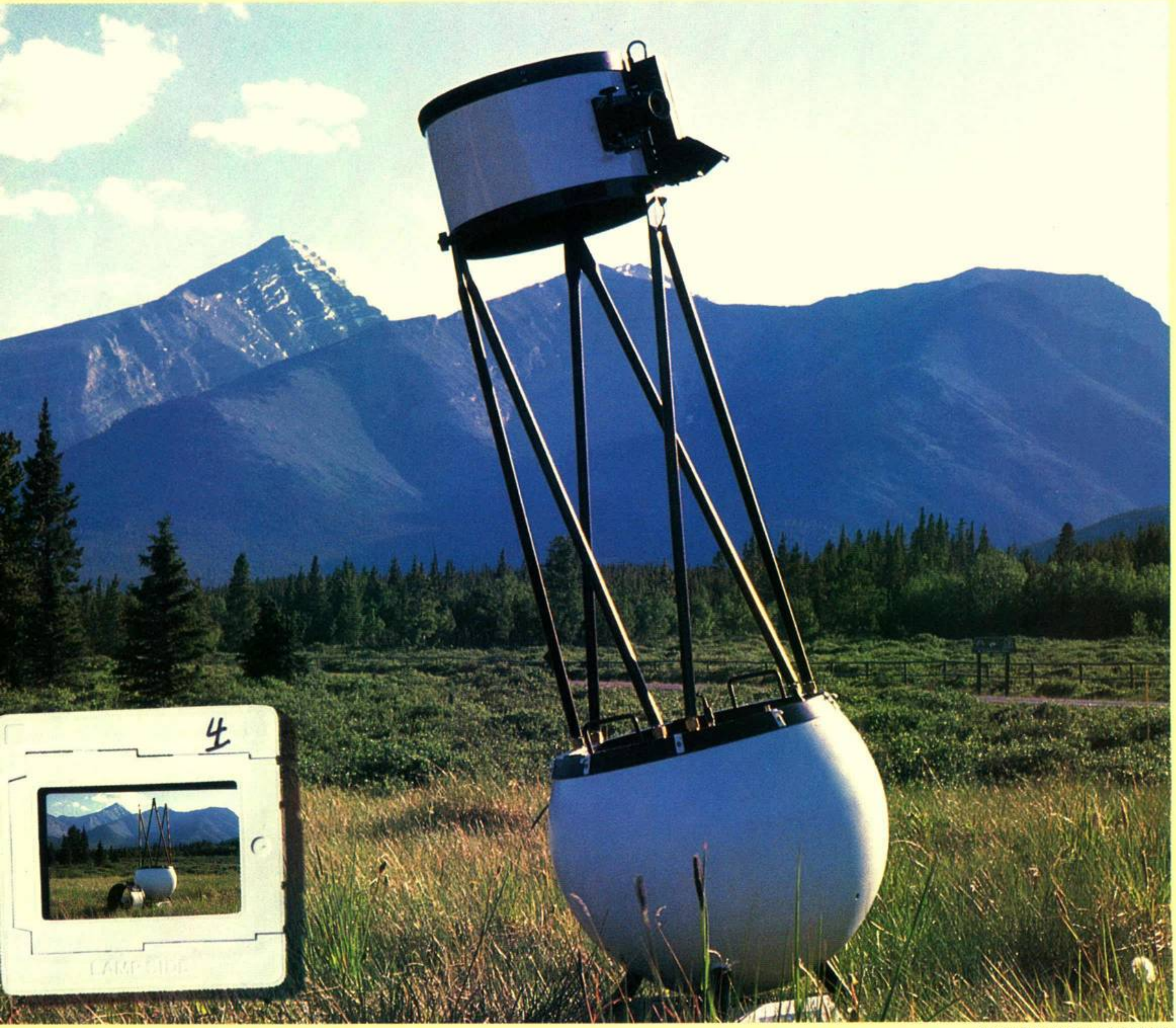
Dancing in the Stars

A unique feature of the PortaBall is its 22-inch-diameter spherical base and a low wooden stand that supports the sphere on three Teflon pads. The sphere is made of spun aluminum painstakingly hand sanded by Smitka and then treated with a durable powder coat finish. The sphere acts as a giant bearing that allows the telescope to swing around the sky or quickly rotate to place the eyepiece and Telrad finder at a convenient angle.

The PortaBall's ball-and-socket style of movement has another significant advantage: You can follow an object easily even if it is straight overhead at the zenith. No more "Dobson's hole," the place near the zenith you inevitably bypass with a conventional Dobsonian because objects there are too awkward to aim at and track. But with the PortaBall, following objects at the zenith is just as easy as following them anywhere else in the sky.

In addition, Smitka custom-tailors each PortaBall wood stand to place the eyepiece at standing eye level for each owner when the telescope is aimed straight up. And thanks to the tube's free rotation, you can observe targets low in the sky when either standing or seated.

Combine all these traits, and the result is a telescope that gives an unprecedented sense of celestial freedom. I found I could whip around the sky from one object to another without having to climb ladders that per-



All photos by Alan Dyer unless noted

petually seem to get in the way. I had no concern about whether the next target would be too difficult to aim at or the eyepiece or finder too awkward to reach.

Other people I've met at star parties who have had the chance to handle a PortaBall have been similarly impressed. As one user put it, "I could have danced all night!"

First-time Assembly

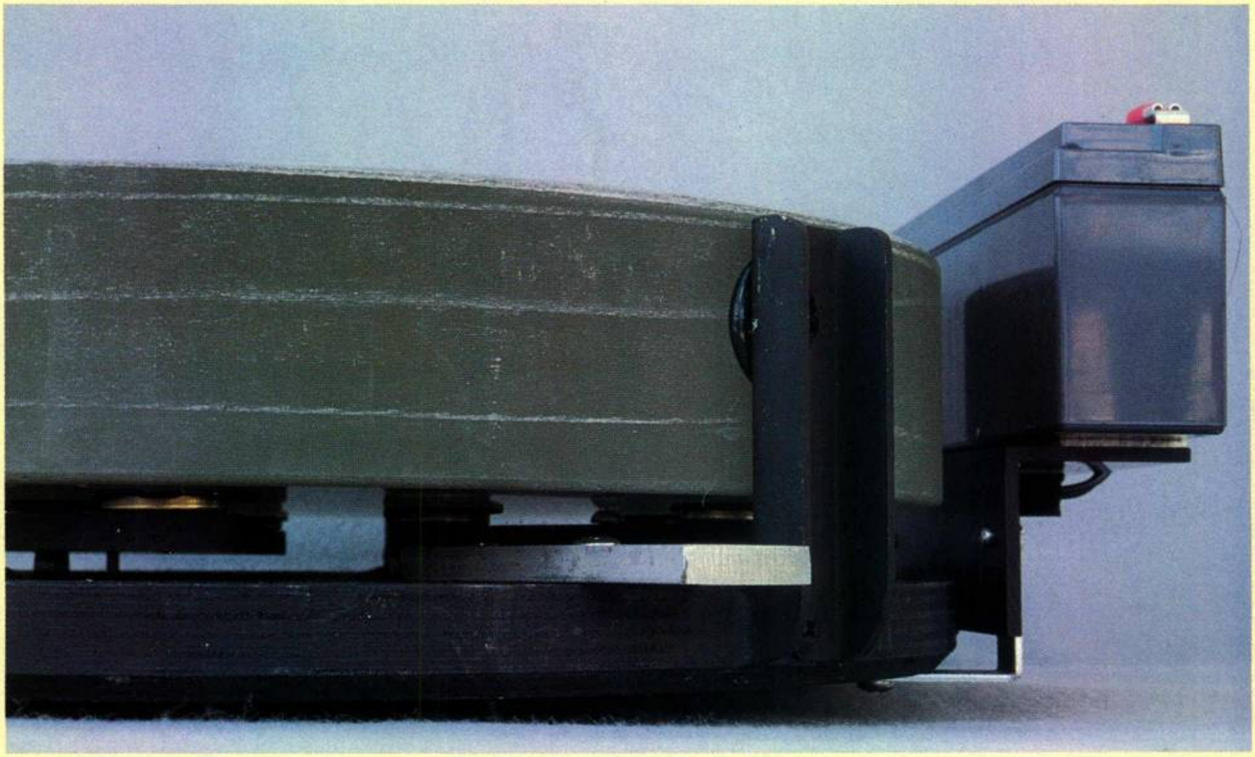
Because the entire telescope rotates, the PortaBall's primary mirror simply can't rest loose in its cell as it does in many Dobsonians. Smitka secures the mirror to its cell with patches of silicone glue between the mirror and nine metal flotation points. He also glues the edge of the mirror to three vertical metal tabs. Unlike traditional mirror cells, this one has no clips clamping the mirror from the front. Although an unorthodox design, the cell always held the 2-inch-thick mirror securely in collimation while producing no detectable astigmatism from pinched optics.

Removing the mirror completely from the cell for realuminizing, however, will require you to separate it from the blobs of glue with a knife and then reglue it when you reinstall the mirror. This is a chore you may never need to do or perhaps only once or twice in the telescope's life.

However, a necessary task for all new owners is to secure the mirror-and-cell assembly that's packed separately inside the metal sphere. This requires lining up three tapped flanges on the cell with spring-loaded bolts inside the sphere. These bolts secure the cell in place and act as the collimation adjustments. Installing the mirror is simple but handling the 30-pound mirror assembly inside the dark sphere is a bit unnerving as a first step in using this telescope. Once it's secured, though, you don't need to remove the mirror for routine transportation or even for regular cleaning. Smitka supplies instructions for cleaning the mirror in place inside the sphere, an approach I found worked quite well.

Nightly Assembly

Transportability is the most attractive feature of the PortaBall. The



THE MIRROR IS HELD in its cell by dabs of silicone glue on the flotation points (left) and vertical tabs (right). The optional rechargeable battery (far right) powers options and acts as a counterweight.

THE TRIANGULAR BASE has three Teflon pads that support the sphere and serve as the bearing points. Keeping these clean and the surface of the sphere waxed is essential maintenance.

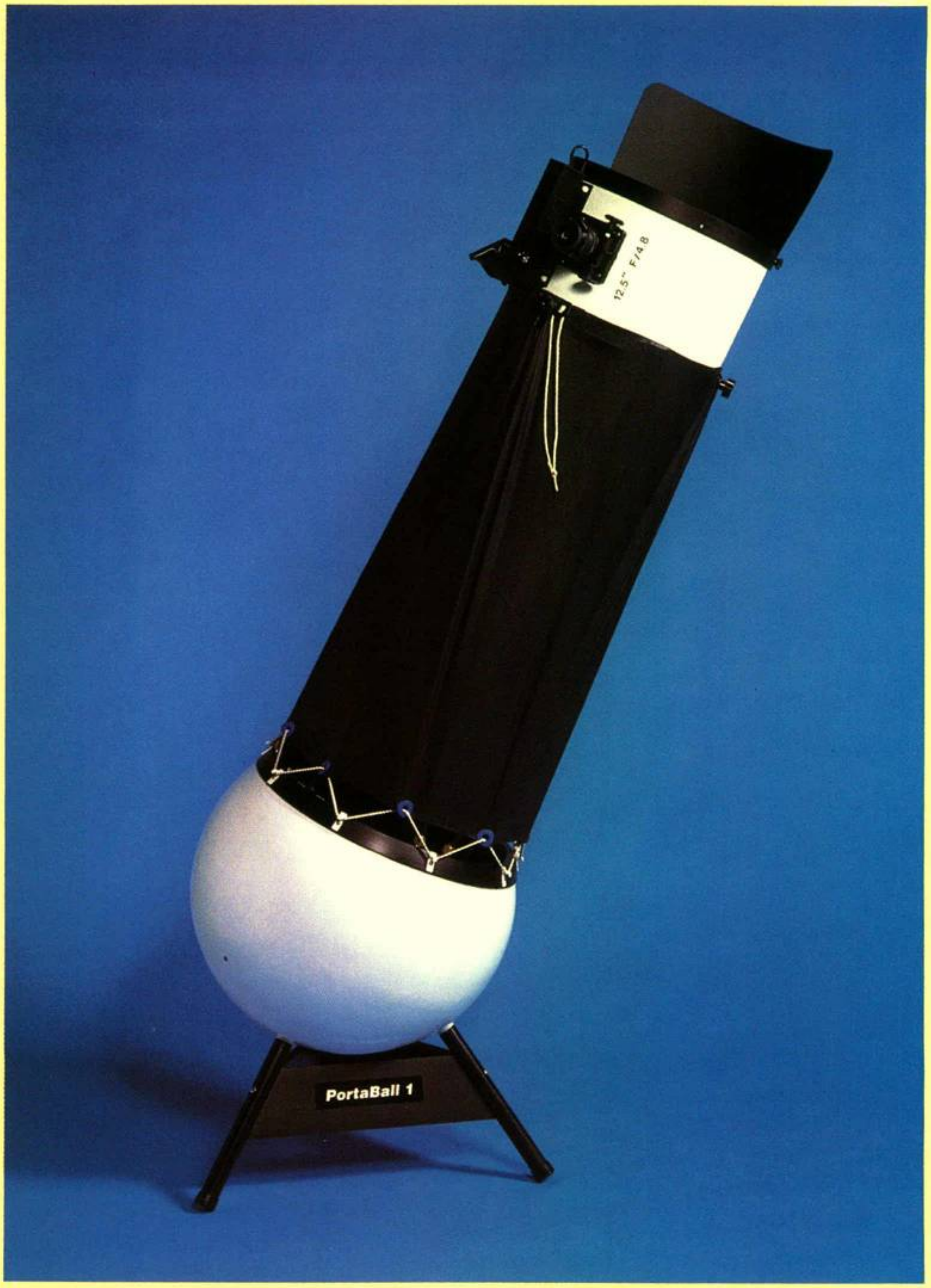
PortaBall 1

cylindrical upper end nests neatly inside the sphere while the three-foot-long truss poles take up little room in their separate storage tube. The entire package will sit on the front seat of most cars, making this the most portable commercial 12.5-inch telescope I've seen.

Once at the site, you can use built-in handles to lower the 55-pound sphere onto its triangular stand. Because of its size and shape, the sphere is awkward to carry any distance. As an option, Smitka offers a wheelbarrowlike transporter for rolling the telescope around — I'd recommend it if you regularly set up far from your vehicle or home.

Assembling the telescope requires no tools, a real plus. With the sphere on the stand, six truss poles (two less than most truss-tube Dobsonians) screw into a threaded socket on the rim of the sphere. I like the fact that the poles do not flop around, making it easy to attach the upper end. All the poles are the same, unless you have the optional upper-end electrical package, in which case one pole has an electrical cable inside it that screws into the socket near the electrical jack.

Next, to attach the upper end, each pair of truss poles slips into one of three bolts on the upper end, and then a large knob screws onto each bolt. The upper end is light and easy to hold in place with one hand while you secure it. You do not need a ladder to lift it onto the poles.



TO BLOCK STRAY LIGHT and reduce unwanted glare, an optional nylon light shroud slips over the open trusses and a tube extension fits on the upper end.

ASTRONOMY: Jim Forbes

The only inconvenience I find is that the black knobs that attach the poles to the upper end aren't captive. I often drop one onto the ground during assembly. (A cover normally rests over the primary mirror to protect it from wayward parts.) Apart from that, the no-tool assembly is painless and quick, taking five minutes at most. Once set up, the telescope is solid and well-damped, requiring only one to two seconds to settle down after a rap to the upper end.

Wax On, Wax Off

Conventional Dobsonians have a well-defined motion in altitude. A heavy eyepiece at the top is balanced by adding extra weight to the bottom. With a PortaBall, achieving proper balance is more complicated. The telescope must be balanced radially as well as lengthwise, otherwise it slowly rotates or shifts horizontally. When ordering a PortaBall, you specify the heaviest eyepiece you intend to use. Smitka then installs the proper amount of counterweight at the bottom of the sphere to balance your telescope accordingly.

The telescope I tested came balanced to handle a 15-ounce 22mm Panoptic, the heaviest eyepiece I use. I found no problems switching to lighter eyepieces such as Plössls and orthoscopics weighing only two ounces — the telescope was not "bottom-heavy" with these eyepieces. When the telescope was without an eyepiece altogether, it still stayed put.

To check the opposite extreme, I inserted a big 27-ounce eyepiece, a 35mm Tele Vue Panoptic. Despite the fact the scope wasn't built to take it, I found that unless the telescope was aimed very low, it still behaved well and did not sink or spin under the weight of the jumbo eyepiece. Nevertheless, unlike normal Dobsonians, PortaBall does have restrictions on what can be attached — do not plan to add a large finderscope and use heavy eyepieces, for example.

Crucial to this telescope's balance and smooth motion is controlling the friction of the sphere. Its enamel-like surface must be covered with a silicone-based car wax to give it the right degree of slipperiness. If it's too slippery (as the scope was when I first got it), the telescope moves too easily — a gust of wind or simply sliding out an eyepiece will knock it off target. If the sphere has little or no wax, stiction makes it difficult to move the telescope smoothly.

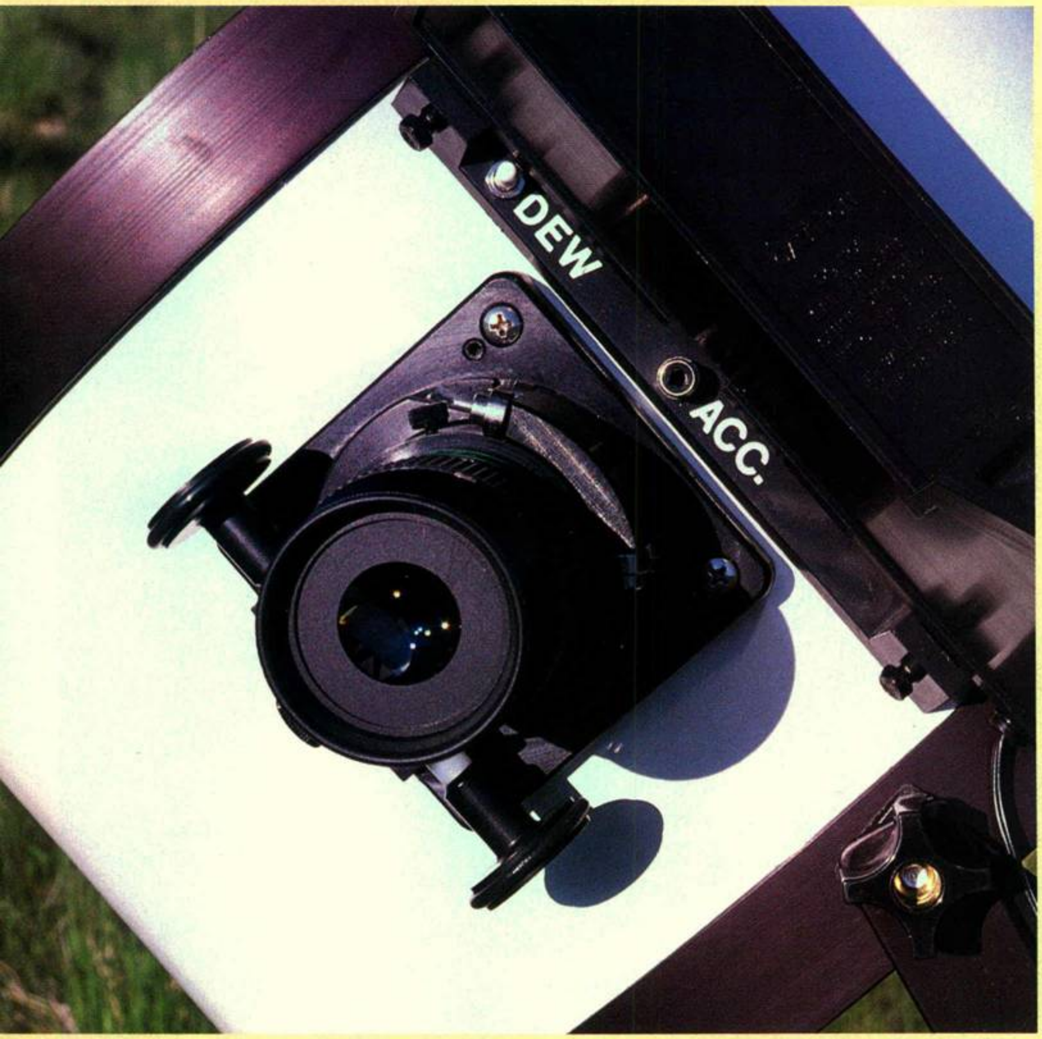
To reduce slipperiness, a wipe with denatured alcohol will remove unwanted wax. More often I found the opposite necessary. I had to reapply wax every few weeks to eliminate stickiness in the motion.

Despite the sphere's sensitivity to proper coating, I found heavy dew and frost made no difference to the movement of the telescope. However, care must be taken not to bang the metal sphere. A dent in it will cause a bump in the motion of the telescope when one of the three Teflon pads hits the dent.

Another caveat is that the telescope's omnidirectional movement and lack of defined axes means you cannot attach encoders for computerized finding aids. You need to rely on the Telrad finder to locate objects.

Optics Check

The PortaBall's mirrors are made by Galaxy Optics. For its 12.5-inch mirrors, Galaxy promises an accuracy



THE UPPER END FEATURES a 2-inch focuser and a switch that turns on anti-dew heaters or a collimation light. A switch on the sphere operates a cooling fan beneath the main mirror.

in the actual reflected wavefront (not just in the surface of the mirror) of at least 1/13-wave in red light and a Strehl ratio of at least 0.80 (with 0.90 typical). The important statistic is a weighted measure of the effect of all the mirror's bumps and flaws. The Strehl ratio measures the fraction of a star's light the mirror focuses into the diffraction-produced Airy disk. A Strehl ratio of 1.0 is theoretical perfection. A mirror with a Strehl ratio of 0.80 is still superb and good enough to be labeled "diffraction limited." (For more information on optics tests, see Checking the Optics in "The 14.5-inch Starsplitter," February 1994.)

The test mirror reviewed was claimed to be better than Galaxy's minimum specs. A laser interferogram that came with the telescope indicated a wavefront accuracy of 1/29-wave when sampled at nearly 3,000 points over the surface. The Strehl ratio was a claimed 0.91. The secondary mirror's wavefront accuracy was measured by Galaxy to be 1/45-wave.

Galaxy Optics' owner John Hudek downplays the importance of the more familiar peak-to-valley figures often used by amateur astronomers. Peak-to-valley is a ruthless measure of the size of the largest single error in a mirror. However, an error that occupies only a small fraction of a mirror's surface (perhaps affecting only one of the 3,000 test points) can degrade the p-to-v figure yet have little effect on image quality. As it was, the peak-to-valley wavefront error from the reviewed primary was claimed to be an excellent 1/5 wave.

Without laser interferometry apparatus at my disposal, I was unable to confirm these impressive numbers. But stars showed flawless and virtually identical diffraction patterns on either side of focus. There was no sign of spherical aberration, surface roughness, astigmatism, or zonal errors. A Ronchi grating placed near the focus with three lines showing exhibited clean straight bands, another indication of minimal spherical aberration and zonal errors.

Poor-to-average seeing on most test nights meant that stars usually failed to show distinct Airy disks and diffraction rings when in focus. This is not uncommon with larger aperture telescopes. During moments of better seeing, faint stars did tighten up into fleeting Airy disks with a faint diffraction ring. Under these conditions, globular clusters at high power looked like swarms of pinpoints. Jupiter showed rich details such as festoons along the edge of the North Equatorial Belt, the large white ovals in the South Temperate Belt, and hints of structure within the Red Spot.

Clearly, this was a first class set of optics suitable for all types of viewing, both deep-sky and planetary. But good optics mean nothing if they are out of collimation. Both the primary and secondary mirrors come marked with center dots to aid collimation. Using the supplied Cheshire eyepiece tool, it was easy to align the dots on the mirrors and achieve perfect collimation indoors without ever looking at a star. However, I felt that the instruction manual, like most, could do more to clearly illustrate how to perform the adjustments.

Once collimated, the telescope stayed that way even after coming apart and going back together several times. When it needed a touch-up, the three hand knobs that extend up from the primary mirror adjusted the tilt of the mirror from the front, making it easy to perform a tweak and quickly check the result in the eyepiece. I did find that the Novak secondary mirror holder rotated loose once, requiring a firm retightening and recollimating.

Conveniences Galore

One trait of the PortaBall is that the sphere completely encloses the primary mirror, with no "flow-through" ventilation possible. Initially, I was concerned this might cause unwanted tube currents from pools of trapped warm air. The review telescope came with an optional cooling fan to circulate air. However, even without the fan going, I found that on winter nights the PortaBall took only an hour or so to cool down from room temperature and produce clean images affected only by the atmosphere. On the test scope, a loose connection under the

MAG1 PORTABALL

Standard specifications

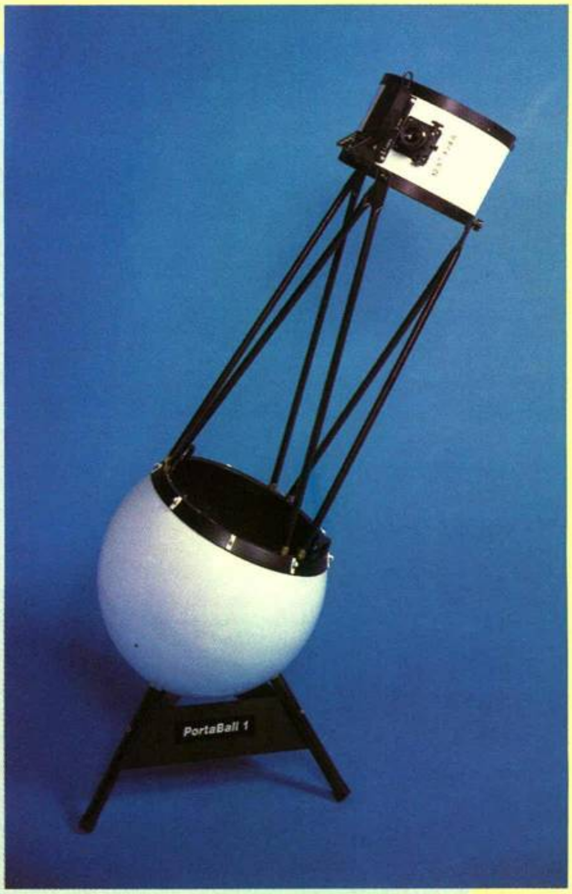
Optics manufacturer	Galaxy Optics
Aperture	12.5 inches
Focal ratio	4.8
Primary mirror thickness	2 inches (6:1)
Secondary size (minor axis)	2.6 inches
Secondary obstruction (by diameter)	21%
Size of focuser	2 inches
Finderscope	Telrad reflex-style
Total telescope weight	67 pounds
Weight of heaviest component (sphere with mirror)	55 pounds
Eyepiece height at zenith	61 to 79 inches*
Manufacturer-direct price	$2,395
Promised delivery time	8 to 10 weeks

* Height of telescope is made-to-order for each customer.

Optional accessories

Enhanced (96%) aluminum coatings	$150
Laser interferogram documentation	$250
Light shroud and tube extension	$95
JMI Crayford-style NGF-3 focuser	$85
Electrical package #1 (battery, fan, primary LED)	$115
Electrical package #2 (anti-dew heaters, secondary LED)	$94
Battery eliminator/charger	$65
Wheeled transporter	$79

MAG1 Instruments, 16342 Coachlight Drive, New Berlin, WI 53151, (414) 785-0926.



ASTRONOMY: Jim Forbes

mirror cell caused the fan to be intermittent, but this was easily fixed.

Smitka offers a number of other electrical options: power to the Telrad reticle, heater circuits to keep dew off the secondary mirror and Telrad faceplate, and red LEDs that shine onto the secondary and primary mirrors. These light up the center dots, making it easy to collimate the mirrors at night. The upper end electrical package also includes an RCA jack to plug in other 12-volt accessories such as an eyepiece heater coil.

The telescope's electrical options are powered by an internal 12-volt rechargeable battery. It lasts only one evening with the heater circuits going, but holds for many evenings if powering only the Telrad and collimation LEDs. The heater circuits work well in keeping the dew-prone Telrad perfectly clear on damp nights. While the internal battery and built-in wiring neatly eliminate any tangle of cables, recharging the battery requires moving the heavy sphere to an AC outlet — you can't just carry the battery.

An option buyers should purchase is a nylon light shroud that slips over the truss poles to keep stray light out of the tube assembly. This option also includes a tube extension that attaches to the front of the telescope with Velcro to block light from entering the eyepiece directly from the top. This was a necessary item; without it ultra-wide-field eyepieces exhibit some flare from stray light.

The standard focuser is a Novak helical unit. The test scope, however, came with the optional JMI NGF-3 focuser. This Crayford-style focuser proved very smooth and precise. It had enough travel to accommodate all my eyepieces, from 2-inch wide-angle models to high-power 1.25-inch eyepieces. My only complaint is that the little set screws that hold the eyepiece are hard to adjust with gloves on.

Standard niceties are mirror covers, including a handy plastic tumbler that slips over the secondary, a plastic rain cover for leaving the telescope out overnight, a padded vinyl bag for covering the sphere and its contents when the PortaBall is broken down for storage, and a hard plastic tube for neatly storing the truss poles.

These touches and the professional grade of finish throughout add immeasurably to the pleasure of using this telescope. The PortaBall has clearly been designed by someone who uses telescopes under real-world conditions and knows the utility of features such as anti-dew heaters and collimation aids.

Call it the best endorsement a product can receive from a reviewer — I liked the PortaBall so much I bought the test unit. It has since become my most used visual telescope. □

Alan Dyer, a former editor at ASTRONOMY, is currently a producer at the Alberta Science Centre in Calgary.

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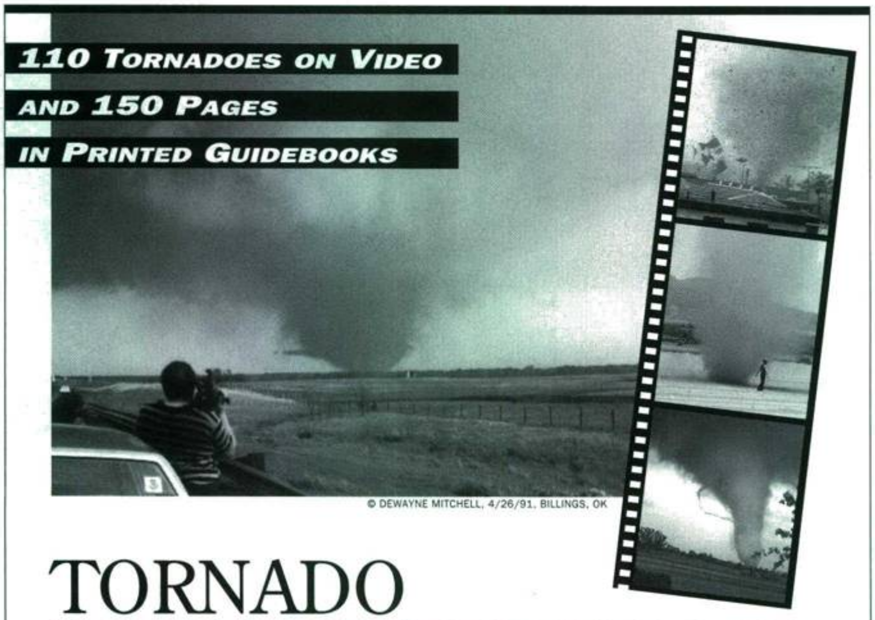

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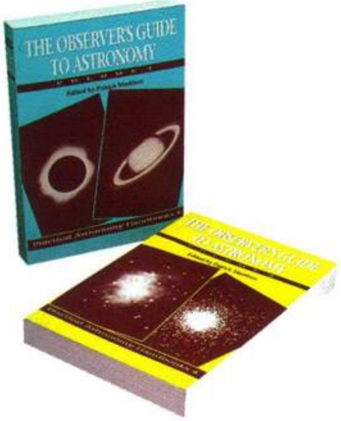
ASTRO BOOKS

Yes, You Can Do Science

The Observer's Guide to Astronomy

Edited by Patrick Martinez, (Cambridge University Press, 1994), Vol. 1, ISBN 0-521-37945-8 (softcover), 0-521-37068-X (hardcover), 594 pages; Vol. 2, ISBN 0-521-45898-6 (softcover), 0-521-45265-1 (hardcover), 551 pages; hardcover set: $79.95, softcover: $34.95.



Some observers amble out into the backyard, content to grab a glance at the sky for the sake of sheer appreciation. Amateur scientists want to get more out of their observing. For them it's not enough to enjoy the shadowplay of light on the Moon's surface, it's more fascinating to find out about the Moon's nature. Certainly there must be projects, techniques, and equipment that allow backyard astronomers to discover the heights of lunar mountains, or with a spectroscope, glimpse the chemical nature of lunar soil.

Well, there are ways to dabble in science from your backyard and this two-volume set exposes you to them. And not just for the Moon, but the Sun, the planets, asteroids, comets, variable stars, aurorae, meteors, and beyond. *Observer's Guide* is not a gazetteer or sightseer's guide: It's a user's manual for observational astronomy. Facts are presented in the context of scientific data-gathering one can perform with modest-sized telescopes.

Throughout *Observer's Guide*, readers are drilled in techniques that yield insights into the workings of astronomy. No longer do you just watch a star wink out behind the Moon's limb (an occultation);

you meticulously time the event and note other details that shed light on the Moon's motion and its shape or give glimpses into the nature of the star itself. Or during a solar eclipse, you can use photographic techniques to explore the elusive F corona, where the Sun's atmosphere mingles with interplanetary dust. The F corona's brightness indexes how much material is in the region.

Volume one starts with the Sun, progresses to the Moon and then on to the planets, planetary satellites, asteroids, and comets. It concludes with a chapter on occultations by both the Moon and asteroids and on observing Earth satellites. The second volume explores aurorae, then moves on to meteors, double and multiple stars, variable stars, deep-sky objects, and novae and supernovae. Concluding chapters give more detail on techniques and instruments useful for projects outlined in both volumes: plate comparators, astrometry, spectroscopy, photometry, and CCDs.

Observer's Guide is meticulous with the material it chooses to cover in depth but economical with the rest. A 160-page chapter gives tips on how to discover, observe, draw, and photograph comets as well as mathematically plot their motions. The section even demonstrates how to compose a discovery telegram to the International Astronomical Union. Contrast this with the treatment of Mars: Only 20 pages are allotted for a planet renowned for its seasonal features and active atmosphere. All told, *Observer's Guide* devotes only six percent of its content to planetary observing. Even less is devoted to deep-sky observing.

But those concerns ignore that like the proverbial water glass this series is mostly full. The books really shine on topics about the Moon, Sun, planetary satellites, occultations, double stars, variable stars, aurorae, and meteors. In those areas alone, there's a lifetime of work awaiting the amateur. For this reason, if for no other, *The Observer's Guide to Astronomy* deserves a spot on any advanced observer's bookshelf.
— *John Shibley*

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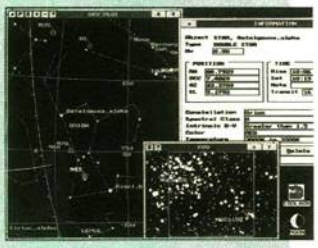

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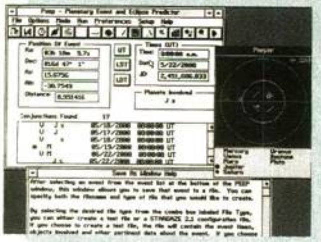

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fictitious Adrian Haller, dreams of meeting Albert Einstein and Isaac Newton in the present and uses the opportunity to explore modern physics through a series of discussions.

The reader is first introduced to Newton's ideas of gravitation and mechanics. Then through Haller's dream, Newton comes to life and discusses early ideas on the nature of light. Soon thereafter, Einstein joins both men for a fuller exploration not only of light, but of antimatter, particle physics, fusion, and relativity (and Einstein's equation $E=mc^2$).

Needless to say, Newton is at times overwhelmed (Haller has to explain how a fluorescent light works) but manages to maintain his intellectual composure, squaring his ideas of physics with those of modern day. Throughout *Equation* there is no math, just an informal and often humorous conversation one might listen to over coffee.

The Superpower Space Race
Robert Reeves, (Plenum Books, 1994), ISBN 0-306-44768-1, 425 pages, hardcover, $28.95.

For more than thirty years, a burst of unmanned space activity touched the Moon and inner planets. Ostensibly, this exploration was done in the name of science, but recast in today's light it was merely an extension of the Cold War.

Space Race examines for each planet unmanned exploration programs mounted by the United States and the USSR in chronological order. Reeves recounts the initial triumphs of the Soviet Luna probes and the bumpy start of U.S. lunar exploration. He also gives a full account of Russia's successful efforts to explore Venus and documents their failures at Mars. Paralleling this are histories of the successful American Mariner, Pioneer, and Viking programs.

During the heady Cold War years, these missions yielded both scientific riches and national prestige and were considered by the superpowers to be well worth the risk and expense. Today mission planners live within the twin constraints of tight budgets and, especially in the case of Russia, political instability. *Space Race* relates a story of exploration the likes of which we will probably never see again.

The Millennial Project
Marshall T. Savage, (Little, Brown and Company, 1994), ISBN 0316-77165, 514 pages, hardcover, $24.95.

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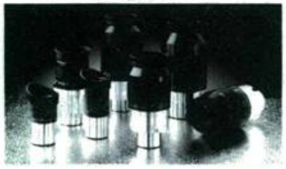

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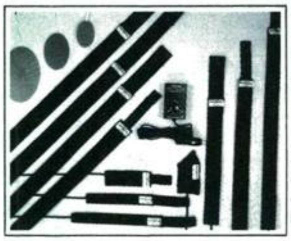

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world where science fact blends with science fiction. In that area where possibilities are limitless, space engineer and author Marshall Savage makes a persuasive (and technologically plausible) case for colonizing the Galaxy in eight steps. The first step is colonizing the sea. Savage explores how technologies related to sea-farming and underwater habitats apply to feeding and sheltering other closed-system colonies.

Then there's getting into space — affordably — using everything from mass driver sleds to laser beams. Once into space, near-Earth and lunar colonies are established. Eventually the atmosphere of Mars is made Earth-like (terraformed) by melting the planet's carbon dioxide polar caps. Then it's off to colonize asteroids and moons of the outer planets, even making a "Dyson Sphere" that surrounds our star at just the right radius to support life. Finally, humans move into the Galaxy.

Of course the economics of carrying out such a plan would be staggering, but intellectually, through *Millennial Project*, the journey's well worth taking.

Rocks From Space

O. Richard Norton, (Mountain Press Publishing Company, 1994), ISBN 0-87842-302-8, 461 pages, softcover, $20.00.

For billions of years, rocks from a variety of places throughout the solar system have been pummeling Earth. Their well-documented effects include mass extinctions of life, craters . . . even dented car trunks. What are these invaders from space? In *Rocks From Space*, Norton looks at meteor falls throughout history and the dynamics of falls and showers, and then lays out meteor morphology.

As a field guide, the book carefully tells readers where to look for meteorites and what to look for in a sample. It outlines meteor types — chondrites, achondrites, irons and stonies — and describes how their characteristics reveal origin. Some meteors come from "parent" asteroids, created out of the collision of two or more asteroids, while others have scientists looking for "lost" parents.

The book also profiles meteorite hunting from a hobbyist's (and professional collector's) point of view. Appendices give information on meteor verification labs and dealers, along with a technique to etch iron meteorites. *Rocks From Space* amply addresses the needs of two audiences, both the armchair astronomer and the meteor hunter. □

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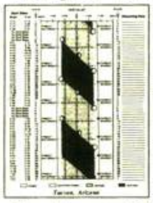

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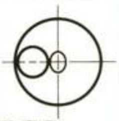

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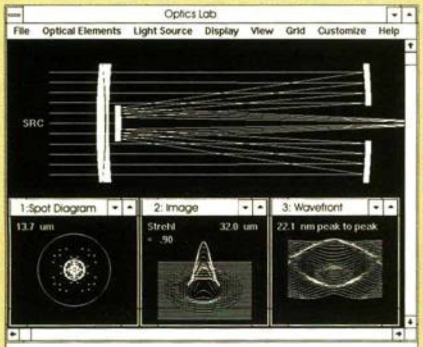

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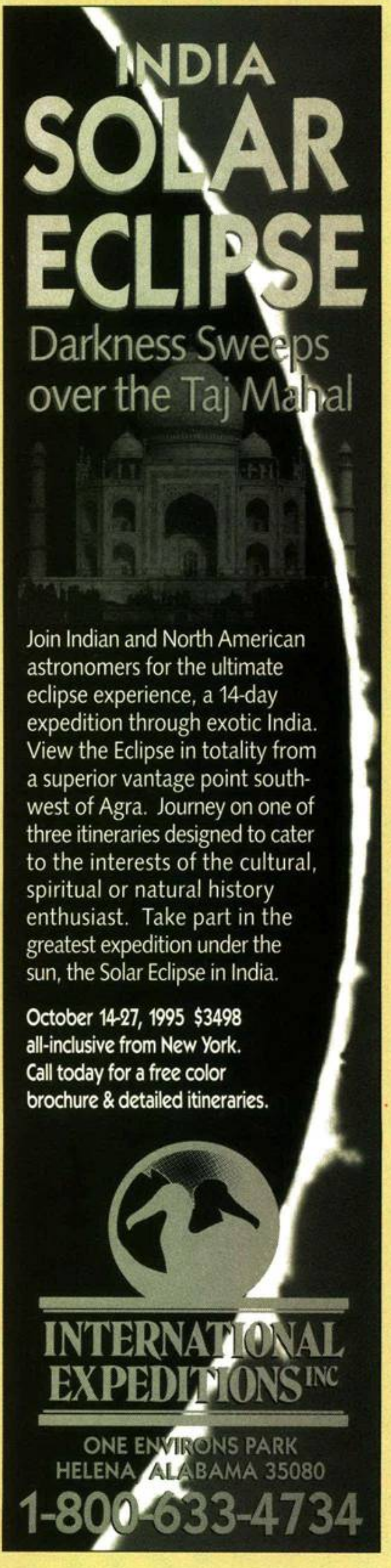

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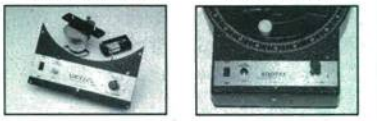

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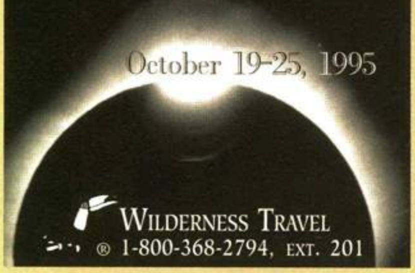

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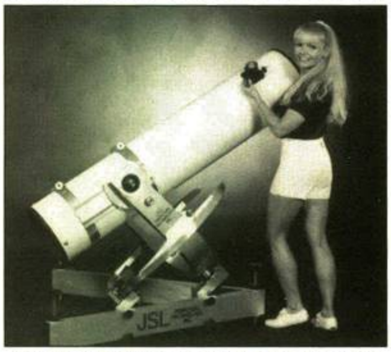

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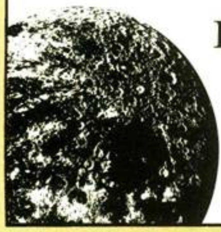

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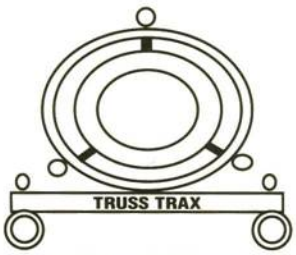

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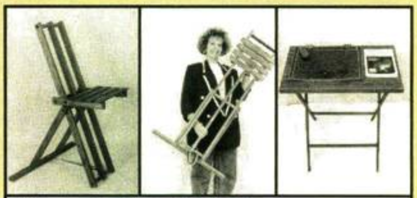

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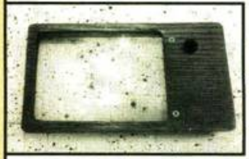

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Light Speed Telescopes, Inc., 3991 Weld County Road 18, Erie, CO 80516, (303) 678-9547. With declination drive: $14,750; without declination drive: $13,950.

On-line Classified Ad Service

The Pegasus Classifieds is an on-line classified service for amateur astronomers who have a home computer and modem. The computer bulletin board system posts ads for telescopes, eyepieces, or any other astronomical item. Sellers write ads directly to the board under appropriate categories. Buyers browse by looking under product headings or by running a key word search routine. To access the service, dial (303) 294-0239 and then create your own user ID password. The system operates at baud rates up to 14,400. Placing ads is free during the system's inaugural year, after which there will be a voluntary fee charged to advertisers equal to one percent the value of any product sold.

The Pegasus Classifieds, P.O. Box 8379, Denver, CO 80201-8379, (800) 326-6686, fax (303) 292-6696.

Takahashi 1.25" Oculars

Takahashi introduces the LE Series, a line of 1.25" modified Plössl eyepieces that offer long eye relief. The LE5mm and LE7.5mm have an eye relief of 10mm; the LE12.5, 9mm; the LE18mm, 13mm; the LE24mm, 17mm; and the LE30mm, 20mm. All eyepieces are multicoated and parfocal and have five elements and apparent fields of view of 52°. The 5mm and 7.5mm eyepieces incorporate extra-low dispersion glass for better contrast.

Texas Nautical Repair Co., 3110 S. Shepherd, Houston, TX 77098, (713) 498-4756. LE5mm, LE7.5mm: $159.50; LE12.5mm, LE18mm, and LE24mm: $148.50; LE30mm: $169.50.

SETI Journal

SETIQuest is a quarterly journal that examines issues related to the search for life in the universe. Articles give the history of SETI efforts, report on projects currently underway, and explore the implications of extraterrestrial life on human society. A "publications watch" surveys popular and scientific literature for books and articles that deal with SETI or exobiology, the biology of life outside of our planet's.

SETIQuest, 174 Concord Street, Peterborough, NH 03458, (603) 924-9631, fax (603) 924-7408, e-mail: setisub@pixelacres.mv.com. One year (four issues: $29; via Internet: $37.

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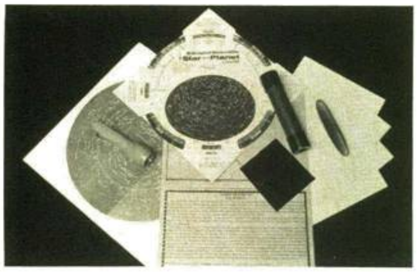

Astronomy Kit for Kids

The A.K.K. Pak brings together equipment and projects that introduce children between ages six and twelve to astronomy. The package includes a sundial kit, spectroscope, planisphere, mini flashlight with red cellophane, "Space Pet" that performs interesting motion tricks, and 250 glow-in-the-dark star decals.

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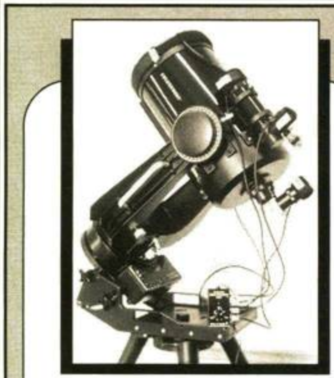
Nikon, 1300 Walt Whitman Road, Melville, NY 11747-3064, (516) 547-4200. 7x50 IF Sports and Marine: $368; 7x50 IF Sports and Marine Compass: $500.

This department presents new product announcements issued by their manufacturers. Product information is as supplied by the manufacturers or distributors. All prices are suggested retail. Suppliers should send their product announcements to the attention of John Shibley.



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Aperture	Mounted	Aperture	Unmounted
2.4"	$49.00	2.4"	$39.00
3.1"	52.00	3.1"	42.00
3.5" to 4"	59.00	3.5 to 4"	49.00
4-1/4" to 5"	74.00	4-1/4" to 5"	64.00
6"	79.00	6"	69.00
8"	95.00	8"	85.00
10"	109.00	10"	99.00
11"	119.00	11"	109.00
12.5" to 13.1"	149.00	12.5" to 13.1"	129.00
14"	169.00	14"	149.00

40mm to 80mm Binoculars - Mounted .... $92.00 pr.

GLASS (Full Aperture) Type 2

Same as type 1, except stainless steel is combined in the coating to provide an even more durable surface that highly resists wear due to excessive handling and ultraviolet radiation. Solar image is also yellow-orange.

Aperture	Mounted	Aperture	Unmounted
2.4"	$62.00	2.4"	$52.00
3.1"	65.00	3.1"	55.00
3.5" to 4"	76.00	3.5 to 4"	66.00
4-1/4" to 5"	96.00	4-1/4" to 5"	86.00
6"	105.00	6"	95.00
8"	125.00	8"	109.00
10"	139.00	10"	129.00
11"	149.00	11"	139.00
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GLASS (Full Aperture) Type 3

Coated to a neutral density of 4 for serious astrophotographers who desire the shortest possible shutter speeds with slow films. Solar image and optical quality same as type 1 & type 2. Type 3 filters are for photographic use only.

Aperture	Mounted	Aperture	Unmounted
2.4"	$79.00	2.4"	$65.00
3.1"	82.00	3.1"	69.00
3.5" to 4"	99.00	3.5 to 4"	79.00
4-1/4" to 5"	125.00	4-1/4" to 5"	110.00
6"	135.00	6"	115.00
8"	159.00	8"	139.00
10"	172.00	10"	152.00
11"	199.00	11"	179.00
12.5" to 13.1"	229.00	12.5" to 13.1"	209.00
14"	259.00	14"	239.00

Types 1 & 2 are for unlimited visual use and general photographic use. Instructions included with all filters, including tips on solar photography.

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(Type 2 coating)

Aperture	Mounted	Aperture	Unmounted
2.4"	$129.00	2.4"	$119.00
3.1"	199.00	3.1"	189.00
3.5" to 4"	269.00	3.5 to 4"	259.00
5"	349.00	5"	339.00
6"	399.00	6"	389.00

Add $15.00 for Type 3 coating.

Off-axis also available for popular brands starting at 6" aperture.

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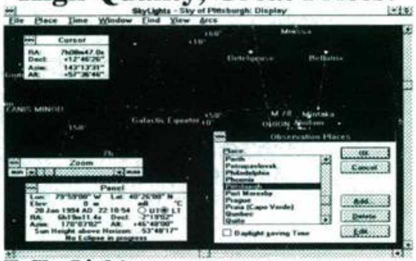

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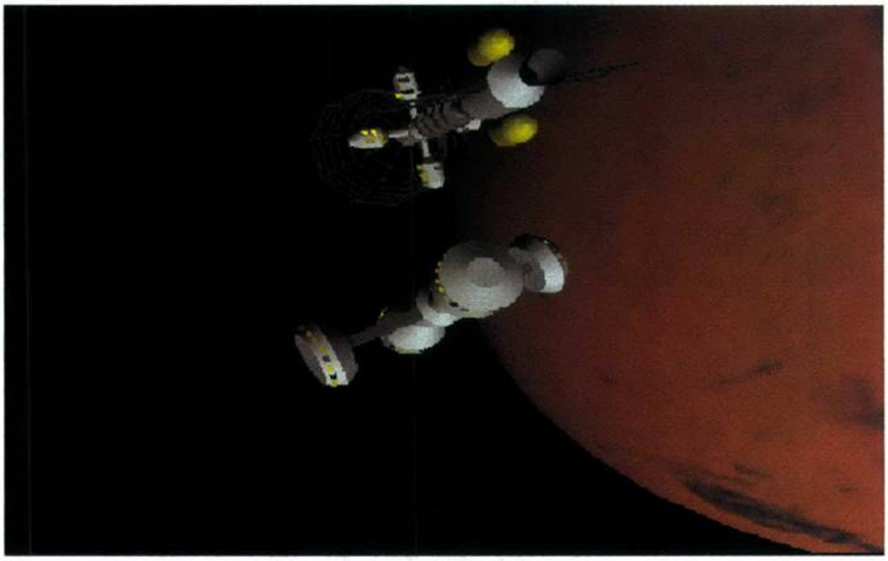
ASTRO BYTES

Trek Through Space

Space Simulator
Microsoft Corporation, One Microsoft Way, Redmond, WA 98052-6399. Price: $64.95. Minimum requirements: 25 MHz 80386-based computer, 2 MB of memory, DOS 5.0, VGA display, and 15 MB of free space on hard disk. Microsoft recommends a mouse, SuperVGA display, joystick, and sound card and an 80486-based computer.



The developers of *Flight Simulator* now present *Space Simulator.* This program lets a user "climb" into a spaceship and zoom off to the Moon, Mars, the star Achernar in the constellation Eridanus, or any other place in our solar system or Milky Way Galaxy. The program provides rendered views of the planets for a "you-are-there" feel. Would-be space travelers can choose from nine spacecraft and visit four space stations. The *Star Pilot's Guide* (also known as the program manual) steps the user through sample missions such as landing the Apollo 17 Lunar Excursion Module on the Moon, visiting the four giant satellites of Jupiter, and flying by an imaginary planetary system of Vega in the constellation Lyra. An autopilot lets novice space pilots learn to navigate space without too much frustration.

This isn't purely a game. *Space Simulator* has a built-in planetarium program for plotting the positions of the planets, stars, and deep-sky objects in the night sky. The manual carefully describes astronomical coordinates and explains terms like acceleration and momentum. It also explains how to raise and lower the orbit of a satellite, use a planet's gravity to sling a spacecraft on a new orbit, and make an elliptical orbit circular.

Prism (1.6)
Astro-Equipements; distributed in the United States by Spectra Astro Systems, 6631 Wilbur Avenue, Suite 30, Reseda, CA 91335, (800) 735-1352, fax (818) 996-7698. Price: $249. Minimum requirements: 80386-based computer, 2 MB of memory, DOS, SuperVGA display, and a hard disk.

Prism is an image-processing program that can handle images up to 4,096 pixels by 4,096 pixels in BMP, FITS, Lynxx, SBIG, TIFF, and user-defined image file formats. The program can calibrate an image using flat and dark frames, enhance the calibrated image, create tricolor images, paste several images together to form a mosaic, and even make a movie from a sequence of images. As part of the preprocessing steps, the user can correct individual pixels or entire rows or columns of bad pixels.

To enhance an image, the user applies mathematical functions called filters to the image. Filters available in *Prism* include high-pass, van Cittert, gradient, unsharp masking, and maximum entropy. Fourier transforms are also available for convolving or deconvolving the image with a function; for example, transforms can get rid of parasitic images caused by noise generated by the CCD camera's power supply.

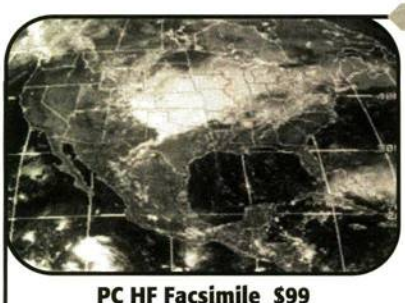
Prism has many other useful functions such as grid projection onto an image. One possible use of this feature is to plot latitude and longitude lines on a planetary image. Another function can manipulate an image geometrically (stretching it, for example) to match the size and orientation of a second image to make comparing the two images easy. The program also provides centroid functions for finding the center of a star's image, astrometry functions for determining an object's position compared to nearby stars, and photometry functions for determining an object's brightness. Other features include 3D plots of brightness in an image and a command-line editor for developing new functions.

Dance of the Planets (2.71) Upgrade

ARC Science Simulations, P.O. Box 1955, Loveland, CO 80539-9907, (800) 759-1642, fax (303) 667-1105. Price: $75 from version 2.5; $50 from version 2.5s or version 2.7 without Diurnal mode (*Stars 8.0*, second edition, upgrade included for users owning first edition); $25 from version 2.7 with Diurnal mode. *Stars 8.0*, second edition, costs $35, contains more than 41,000 stars, and requires version 2.71; the *Stars 10+* optional catalog of over 327,000 stars costs $60 (requires *Stars 8.0*, second edition).

Users of *Dance of the Planets* who haven't upgraded to 2.7 should consider doing so, and users with 2.7 might want to get this upgrade. Version 2.71 enables the use of two new star catalogs. The catalogs use the most accurate stellar positions known (from the *Position and Proper Motion* catalog), and Stars 8.0 now includes information from *Sky Catalogue 2000.0*. The PPM replaces the older and less accurate *Smithsonian Astrophysical Observatory Star Catalog*. In addition to the new features listed for version 2.7 in the September 1994 AstroBytes, 2.71 also adds constellation boundaries, viewing and printing support for stars over a larger range of brightness, and Guidelines, which is an on-screen aid to operating *Dance*.

ARC provides an electronic bulletin board for simulation news, orbital elements, and *Dance* scripts. Turn your



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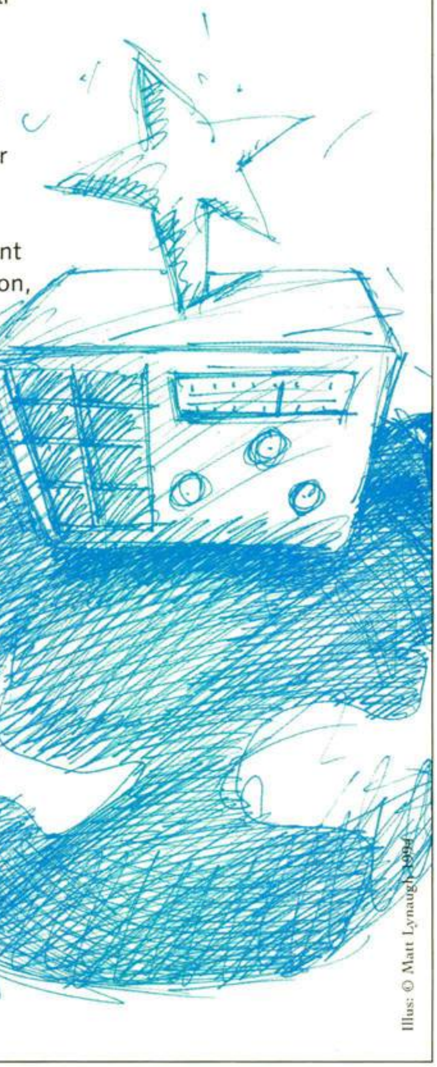

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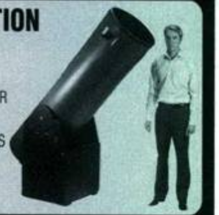

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modem on and dial (303) 667-0122. For users without modems, or overseas users who don't want to pay the international phone charge, ARC now has a BBS-on-Disk that contains the information available to modem users. The cost is $15, which includes shipping (the disk is free to anyone purchasing an upgrade).

Astronomy on the Internet

The Internet is just a collection of computers linked together by high-speed phone wires. But this maze of wires that connects users around the world has unleashed a powerful new means of communication and sharing information, especially about astronomy.

Just as important as the computers and wires is the means for retrieving information from the network. This vehicle, called a front end, enables a user to interact with the resources available through the Internet. One of the best front ends is the World Wide Web, developed by CERN, the European Particle Physics Laboratory in Geneva, Switzerland.

The Web (sometimes abbreviated WWW, pronounced W 3) uses hypertext to retrieve information. Hypertext automatically links text, images, and programs in a manner transparent to the user. For example, suppose a user in Oregon calls up a document from a computer in Iowa. The document may use a series of NASA images but the Iowa computer doesn't store the images with the document. It uses a pointer that automatically connects the user's computer in Oregon to NASA computers in Maryland and California to retrieve the images. This pointer is called a Uniform Resource Locator, usually abbreviated URL.

Users don't directly interact with the Web because it's just a bunch of links. Instead they use a browser such as *Mosaic,* developed by the National Center for Supercomputing Applications in Urbana, Illinois. Mosaic is available for the Macintosh (requires System 7.X, MacTCP, and 4 Mb of memory), PCs using Windows 3.1 (requires an 80386-based computer with 6 Mb of memory), and UNIX-based computers running X-windows. If you have a connection to the Internet, your Internet provider undoubtedly gave you a file transfer program called ftp. Using this program, you can obtain a copy of *Mosaic* from **ftp.ncsa.uiuc.edu**. A popular Windows-based browser is *Cello,* available by ftp from **fatty.law.cornell.edu** in directory /pub/LII/cello (it requires a set of utilities called Winsock TCP/IP). □

MEETINGS & EVENTS

February 27-March 5
Winter Star Party, near Key West, Florida. Sponsored by the Southern Cross Astronomical Society, Inc. Contact Bob or Sharon Grant, 5401 SW 110 Avenue, Miami, FL 33165, (305) 595-8778.

March 13-17
26th Lunar and Planetary Science Conference, Houston, Texas. Co-sponsored by the Lunar and Planetary Institute and the NASA Johnson Space Center. Contact LeBecca Simmons, LPI Publications Department, 3600 Bay Area Boulevard, Houston, TX 77058-1113, (713) 486-2158.

March 18
Astrophoto XI, Moorpark, California. Sponsored by the Ventura County Astronomical Society. Contact Linda Lippman, VCAS, P. O. Box 982, Simi Valley, CA 93062, (805) 520-0206.

March 24-27
MEPCO '95, Violau, Germany. Sponsored by the Working Group of Planetary Observers of Germany. Contact Wolfgang Meyer, Matrinstrasse 1, D-12167 Berlin, Germany, or Daniel Fischer by e-mail to p515dfi@mpifr-bonn.mpg.de or fax 49-2244-80298.

March 30-April 2
The Orange Blossom Special, near Brooksville, Florida. Sponsored by the St. Petersburg Astronomy Club. Contact Dennis and Ellen Farr, 8811 West Broad Street, Tampa, FL 33615, (813) 884-9111.

March 31-April 1
Fifth Annual Messier Night, Clayton, Michigan. Sponsored by the Astronomical Societies of Lenawee and Hillsdale Counties. Contact Wes Boyd, (517) 547-7402.

April 1
1995 Astronomy Workshop, Northeastern Kansas. Contact Brenda Culbertson, 681 Frog Hollow, Harveyville, KS 66431, (913) 589-2405.

April 27-29
Mid-South Star Gaze, French Camp, Mississippi. Sponsored by the Rainwater Observatory. Contact James Hill, FCA, French Camp, MS 39745, (601) 547-6865, or (601) 547-6970.

April 27-30
2nd Annual Peach State Star Gaze, near Jackson, Georgia. Sponsored by the Atlanta Astronomy Club. Contact Ken Poshedly at 3440 Everson Bay Court, Snellville, GA 30278-4463, e-mail ken.poshedly@lightspeed.com.

April 28-29
9th Annual NIAGfest, North Webster, Indiana. Cosponsored by the Northern Indiana Astronomical Groups and the Great Lakes Region of the Astronomical League. Contact Kurt Eberhardt, 3370 E. Kenway Drive, Warsaw, IN 46580, (219) 269-6289.

April 28-30
Delmarva Star Gaze, near Dover, Delaware. Sponsored by the Delmarva Star Gazers Amateur Astronomy Club. Contact Lyle Jones, 230 N. Bardford Street, Dover, DE 19901, (302) 736-9842.

May 21-28
Texas Star Party, Fort Davis, Texas. Sponsored by the Southwest Region of the Astronomical League. Contact TSP Registrar, (915) 426-3202.

May 26-28
Jersey Star Quest V, Sussex, New Jersey. Sponsored by the Amateur Astronomers Association of Princeton, Inc. Contact Larry Smith, 361 Stacy Drive, Belle Mead, NJ 08502.

May 26-29
Riverside Telescope Makers Conference, Camp Oaks, near Big Bear Lake, California. Contact RTMC, Fox & Stephens, CPAs, 9045 Haven Avenue, Suite 109, Rancho Cucamonga, CA 91730, (909) 948-2205 (leave message).

June 24-25
Universe 95, College Park, Maryland. Sponsored by the ASP and ASTRONOMY. Contact the Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112, (415) 337-1110, or fax (415) 337-5205.

June 17-23, 1996
Ninth IUAA General Assembly, Luzern, Switzerland. Sponsored by the International Union of Amateur Astronomers. Contact Andreas Tarnutzer, IUAA, Hirtenhofstrasse 9, CH - 6005 Luzern, Switzerland. ☐

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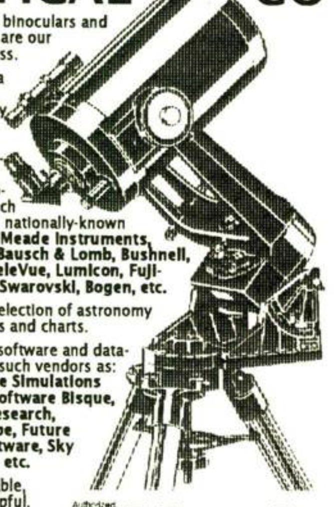

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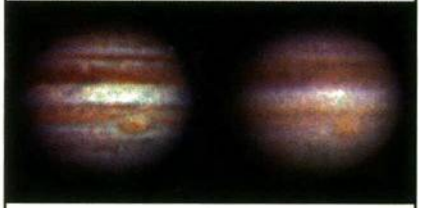

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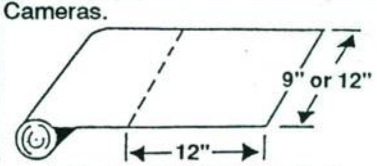

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RESOURCES & PHOTOFACTS

The First New Planet (page 34)

Pale Blue Dot: A Vision of the Human Future in Space, by Carl Sagan, (Random House, 1994). Examines the claims that humans are unique species in the cosmos, discusses how science has changed people's perception of their place in the universe, and assesses the reasons humans have for exploring space.

The Discovery of Neptune by Morton Grosser, (Dover, 1979). Describes Herschel's discovery of Uranus and how the planet's irregular motion revealed Neptune.

Uranus: The Planet, Rings, and Satellites by Ellis Miner, (Ellis Horwood Limited, 1990). Explains in greater detail the discovery of Uranus and what scientists know about the planet after the Voyager spacecraft encounter in 1986.

Polaris the Code Blue Star (page 44)

"Goodbye to Polaris the Cepheid" by J. D. Fernie, Karl W. Kamper, and S. Seager (*Astrophysical Journal*, vol. 416, page 820). Describes the decreasing amplitude of Polaris and its approaching demise as a Cepheid variable.

How Far to Virgo? (page 48)

"Candles to Light the Night" by David J. Eicher, ASTRONOMY, September 1994. A descriptive overview of the distance scale controversy and the various methods of measuring distances in the universe. Provides a full story up to the point of the latest discoveries by Freedman, Pierce, and their coworkers.

Lonely Hearts of the Cosmos, by Dennis Overbye, (HarperCollins, 1991). A wonderful and highly readable look at the community of astronomers and cosmologists struggling to measure the size of the universe. Overbye's keen eye and good descriptions let the reader "hang out" with the scientists as they argue, make observations, and dispute what the results mean.

Zodiacal Light (page 70)

Moons and Planets, by William K. Hartmann, (Wadsworth, 1993). This is the best introduction to planetary science available; great for eager amateurs as well as budding scientists. Has a section on the zodiacal light and the gegenschein.

Astrophotography for the Amateur, by Michael Covington, (Cambridge University Press, 1991). Covington's is an excellent, all-around handbook for taking photos of the sky. He has a section giving detailed instructions for photographing faint "dust in space."

Challenging Planetary Nebulae (page 74)

Burnham's Celestial Handbook by Robert Burnham, Jr., (Dover, 1978). A massive, three-volume compendium of data, photos, observational tips, astrophysical conjecture, and folklore relating to deep-sky objects. Organized by constellation, it provides a handy reference. The work should be used with caution, as a good deal of its data are dated.

Stars and Galaxies; ASTRONOMY's Guide to Exploring the Cosmos, edited by David J. Eicher, (Kalmbach, 1992). A compilation of deep-sky observing articles from ASTRONOMY that presents much information on planetaries. Included are observational tips, directions on finding the objects, charts, tables, and photographs.

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pp. 34-41: Chris Farris; **p. 44:** Jim Baumgardt; **p. 62:** Keith Ward; **p. 64:** Timothy Printy; **p. 68, top:** Peter Ledlie, 4-inch f/8 refractor, Fujicolor 100 film, 1-second exposure; **bottom:** Ronald Royer, 18-inch f/7 Newtonian, Ektachrome 64 sheet film, April 7, 1989; **pp. 70-71:** Michael Terezoni; **p. 72:** Jerry Schad; **p. 74:** Jack Newton; **p. 75:** Evered Kreimer; **p. 76:** Jack Newton; **p. 77:** Stephen Johnston and Jim Brient; **p. 78, top and bottom:** Martin C. Germano; **p. 79, top and bottom:** Martin C. Germano; **p. 109, top:** Huguette Guertin, 700mm lens at f/1.8, Kodak Royal Gold 100 film, 1/2-second exposure on November 3, 1994, from southwest of La Paz, Bolivia; **middle:** David and Glenna Harrington, 3.5-inch Makstov-Cassegrain at f/14, 400 ISO film, 1/500-second on November 3, 1994, from near Sevaruyo, Bolivia; **bottom:** Nelson Falsarella and Fatima Carnicel, 8-inch f/6.5 reflector, 1/2-second exposure on November 3, 1994, from Chapecó, Brazil; **p. 110, top:** Donald C. Parker, 16-inch reflector, STAR-I CCD camera, taken on October 26, 1994; **bottom:** Jack Newton, 25-inch f/5 reflector, ST-6 CCD camera; **p. 111, top:** Ken Blankenship and Dennis Batis, 14-inch SCT at f/7.5, 400 ISO film, 100-minute exposure using a Lumicon Skyfilter; **bottom:** Donald C. Parker, 16-inch reflector, STAR-I CCD camera, taken on October 22, 1994; **p. 112:** Alan Dyer, 80mm lens at f/2.8, Velvia 50 film, two 1/4-second exposure on November 3, 1994. ☐

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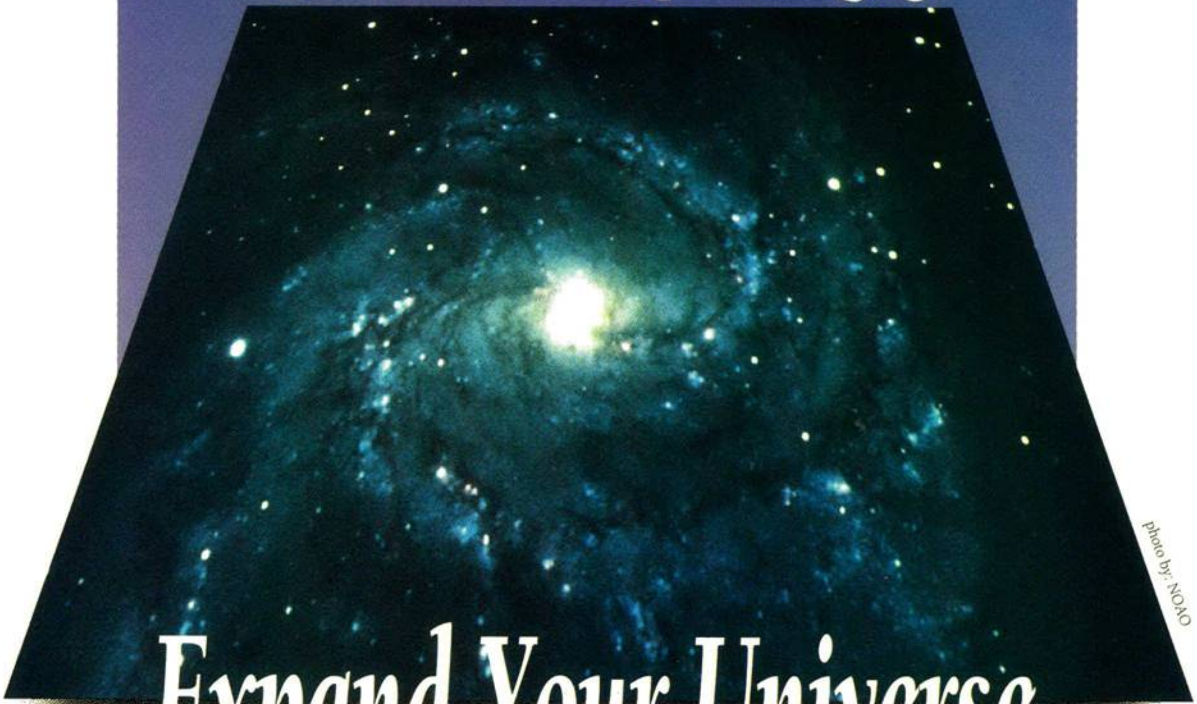

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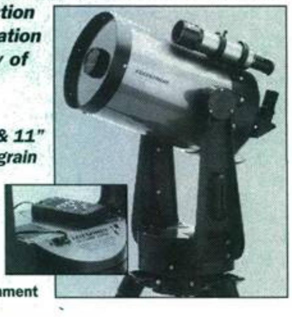

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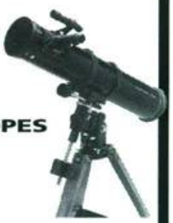

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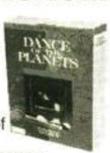

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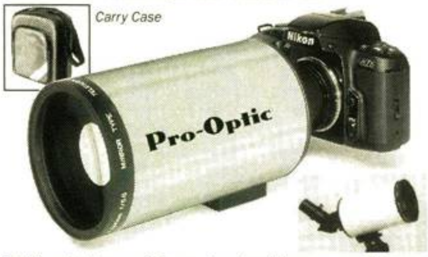

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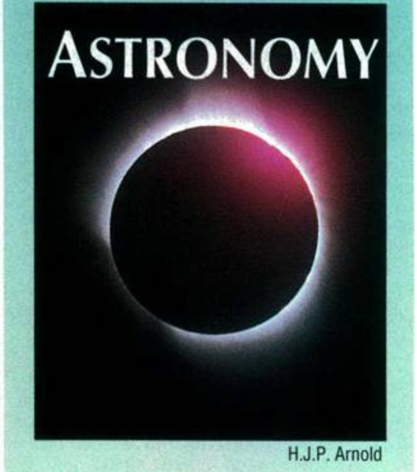

H.J.P. Arnold

THE GREAT SOUTH AMERICAN ECLIPSE What do sunburn, hypoxia, and spell-binding awe have in common? Join Reader Reports as it travels the solar eclipse path from the Andes to the Atlantic.

FIRE FOUNTAINS OF ARISTARCHUS The Moon's last spasm of volcanism sent streamers of lava shooting high into the lunar sky.

RING AROUND THE GALAXY If galaxy A meets galaxy B just right, their union may lead to a ring.

OBSERVER'S GUIDE TO AURORAE From curtains to coronas, the northern lights put on a fascinating display of shape and color.

GALAXY TIME MACHINE Hubble discovers young spirals looking far different than the older ones of today.

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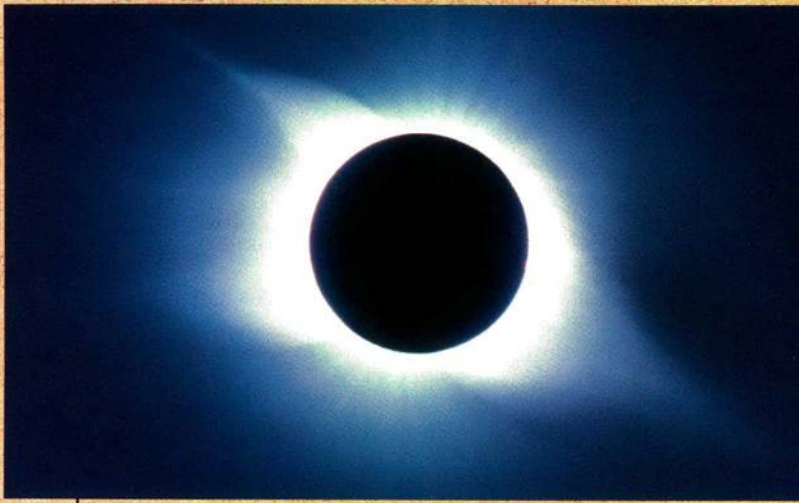
South American Eclipse Memories

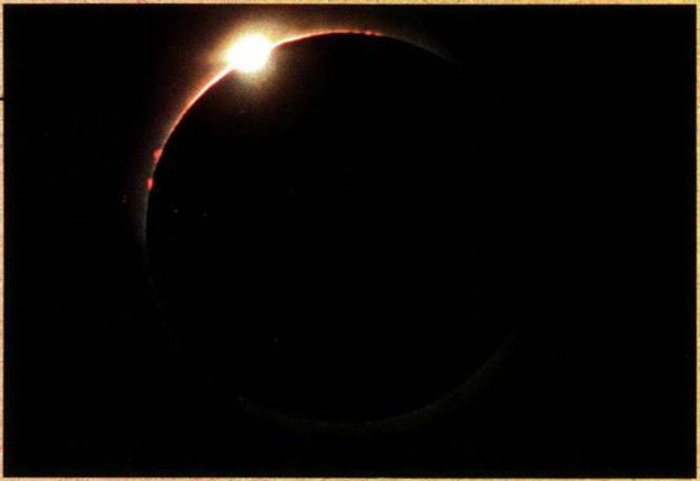
The Moon blocked the Sun on November 3, 1994, creating a total solar eclipse that was visible over a large arc across South America. Viewers in Peru, Chile, Bolivia, Paraguay, Argentina, and Brazil enjoyed up to four minutes of totality during the early morning event, depending on their location relative to the center line. "As we were setting up, the Southern Cross was rising into the dawn twilight," says Alan Dyer, who viewed the eclipse with a Canadian group in Lauca National Park in the Chilean altiplano. Positioned at 15,200 feet, the group looked out toward the Parinacota volcanos, impressively higher cinder cones. "We had selected the site hoping to see the full glory of the Sun's corona set in a crystal clear sky," says Dyer. "As the morning progressed, it became clear we wouldn't be that fortunate. Persistent cirrus clouds drifted across the sky."

But Dyer's group succeeded in viewing all of the nearly three minutes of totality. "The corona was marked by long streamers extending above and below the Sun," he says. "The intricate structure was striking, and Venus lay nearby. Those of us who thought of looking for it could clearly see the crescent phase of Venus through binoculars. As sunlight returned, our group broke out the champagne and compared impressions of the last few minutes of the eclipse. Across the Sun itself, thin cirrus had persisted but failed to spoil the view. We



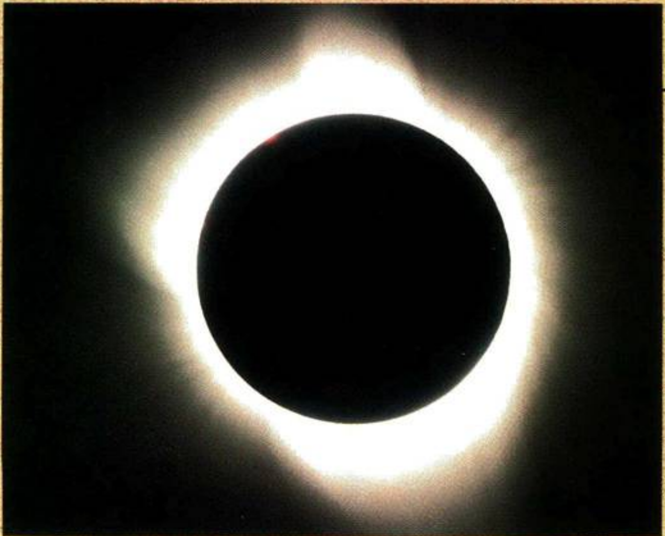
November Solar Eclipse

by Huguette Guertin
(700mm lens at f/1.8, Kodak Royal Gold 100 film, 1/2-second exposure taken November 3, 1994, from southwest of La Paz, Bolivia)



Diamond Ring at Third Contact

by David and Glenna Harrington
(3.5-inch Maksutov-Cassegrain at f/14, 400 ISO film, 1/500-second exposure taken November 3, 1994, from near Sevaruyo, Bolivia)



Polar Brushes in the Sun's Corona

by Nelson Falsarella and Fatima Carnicel
(8-inch f/6.5 reflector, 1/2-second exposure taken November 3, 1994, from Chapecó, Brazil)

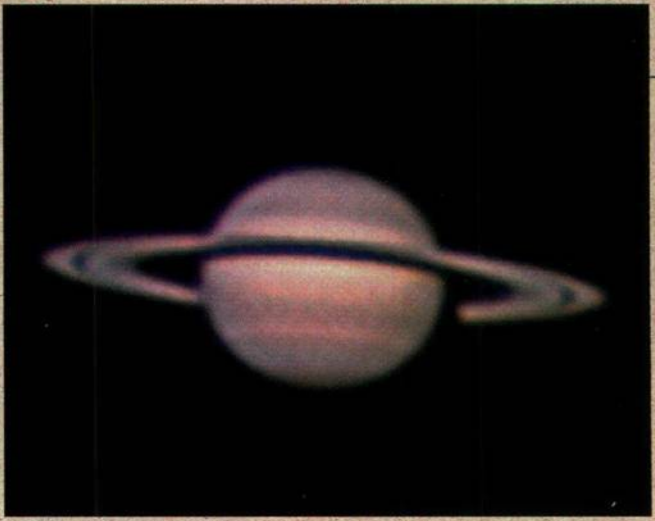
experienced two minutes fifty-eight seconds of totality, brought to an end by a brilliant flash of red as the Moon first uncovered the Sun's chromosphere. Jupiter remained hidden behind a thick band of cirrus cloud, but we saw the details we had come to see and had a glorious time."

Several hundred miles to the southeast, near San Bernardino, Paraguay, Sebastián Carron observed the eclipse with a 300mm lens. A physics student at the University of São Paulo in Brazil, Carron writes "totality was the most beautiful thing I have ever seen. The corona was elongated and glowing brightly. Stars began to shine along with the lights from cars and little towns near distant Lake Ypacaraí sparkled."

Carron and his girlfriend watched for two minutes and four seconds as darkness washed over the land. "The sky appeared different shades of blue," he says, "from dark blue near the Sun to pale blue along the horizon. After the eclipse we applauded what we had seen."

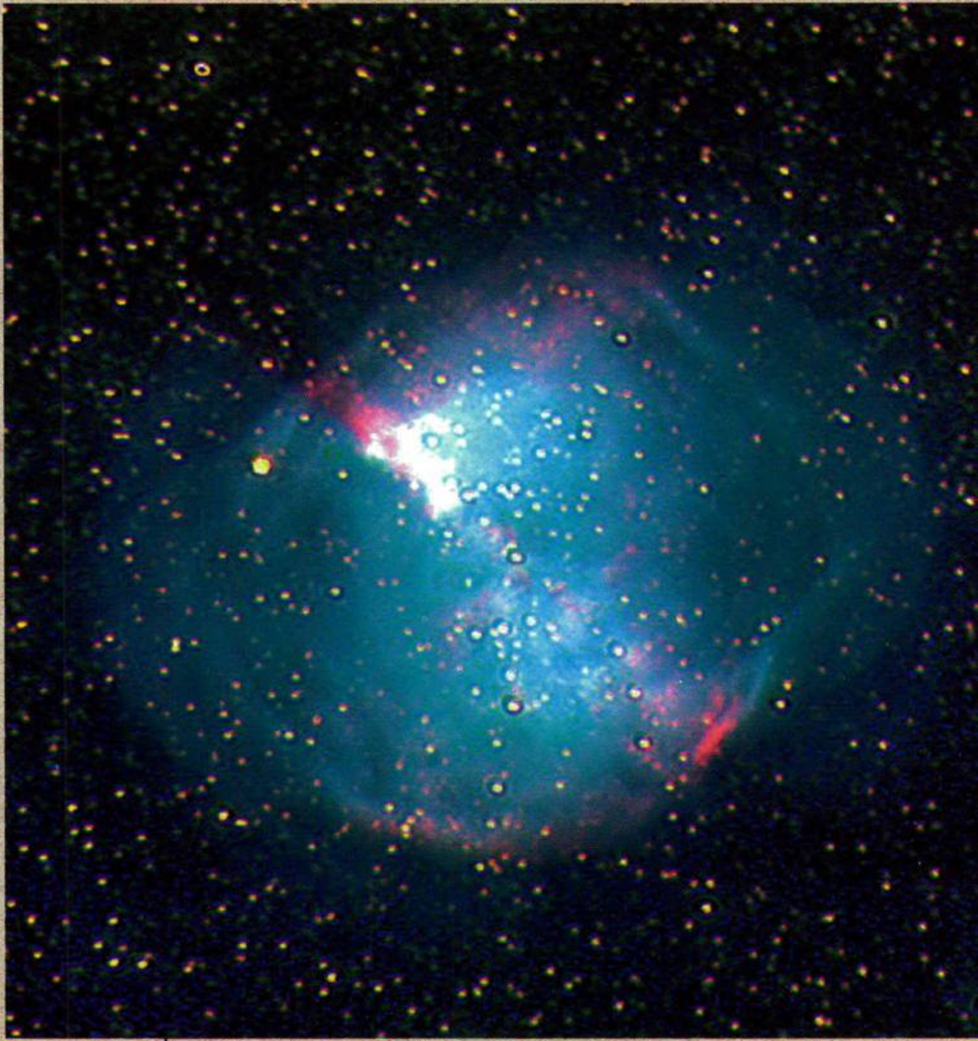
Wayne S. Itokazu viewed the eclipse from Puerto Esperanza, Argentina, where they saw three minutes 48 seconds of totality. "It was like being bathed in very deep twilight," says Itokazu. "Both diamond rings were intense, especially the one that followed third contact, and patchy cloud cover enabled us to see the Moon's shadow receding. It was a lovely eclipse." Watch for extensive coverage of the eclipse in next month's issue. □

ASTRONOMY wants to hear about your observations of the sky. Send reports, sketches, and photographs to David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187. Please label each photo with name, address, and social security number. You may send written reports via the Internet to: 72000. 2704@CompuServe. com



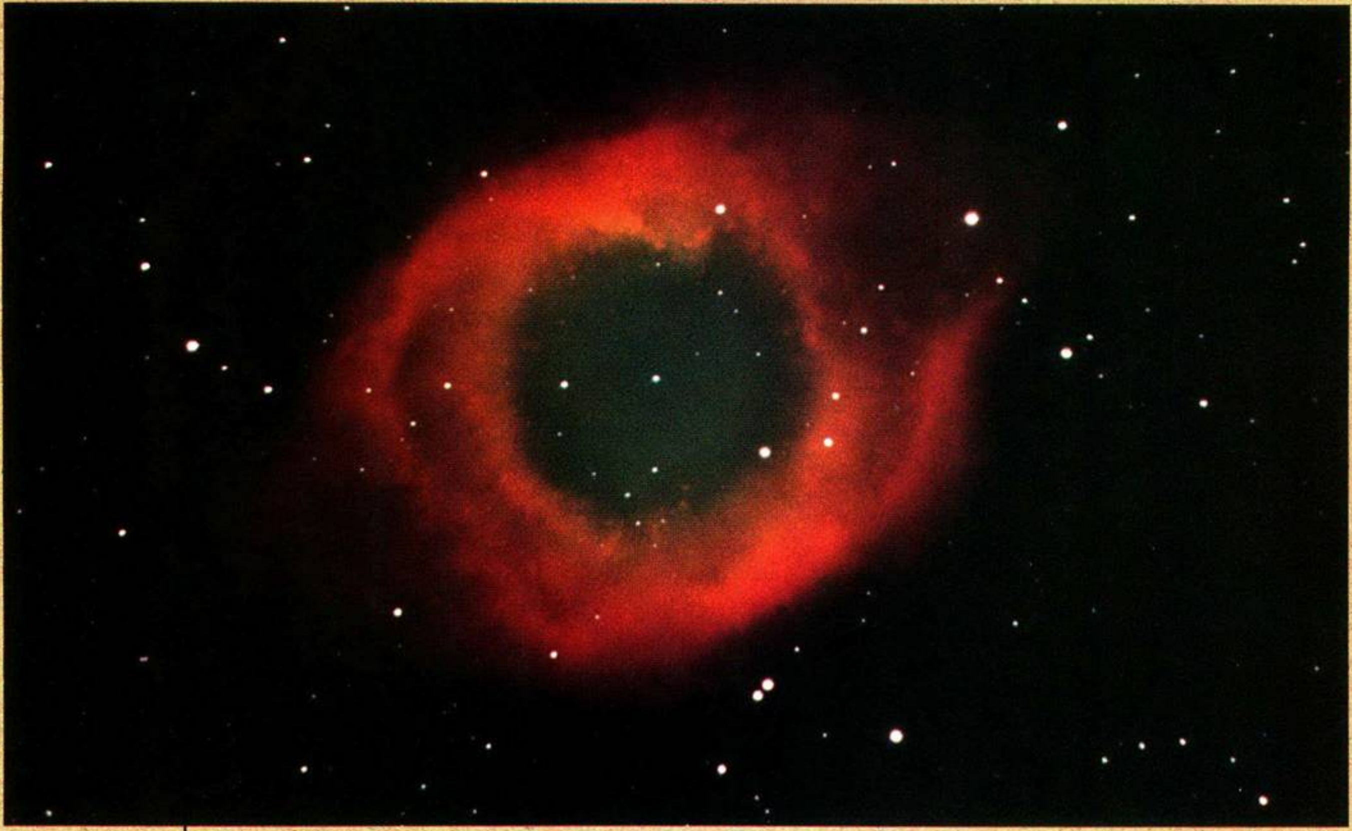
Saturn's Equatorial White Band

by Donald C. Parker (16-inch reflector, STAR-I CCD camera, taken October 26, 1994)



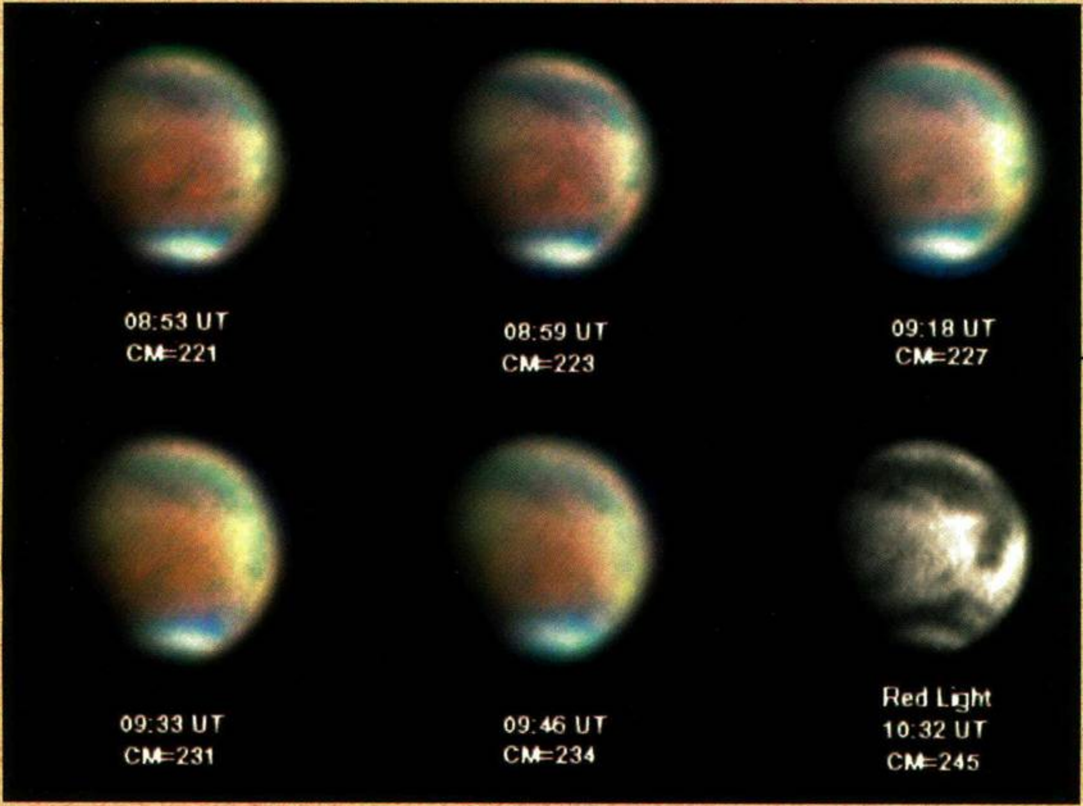
The Dumbbell Nebula (M27)

by Jack Newton (25-inch f/5 reflector, ST-6 CCD camera)



The Helix Nebula (NGC 7293)

by Ken Blankenship and Dennis Batis
(14-inch SCT at f/7.5, 400 ISO film, 100-minute exposure using a Lumicon Skyfilter)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Martian Albedo Features

by Donald C. Parker
(16-inch reflector, STAR-I CCD camera, taken October 22, 1994)

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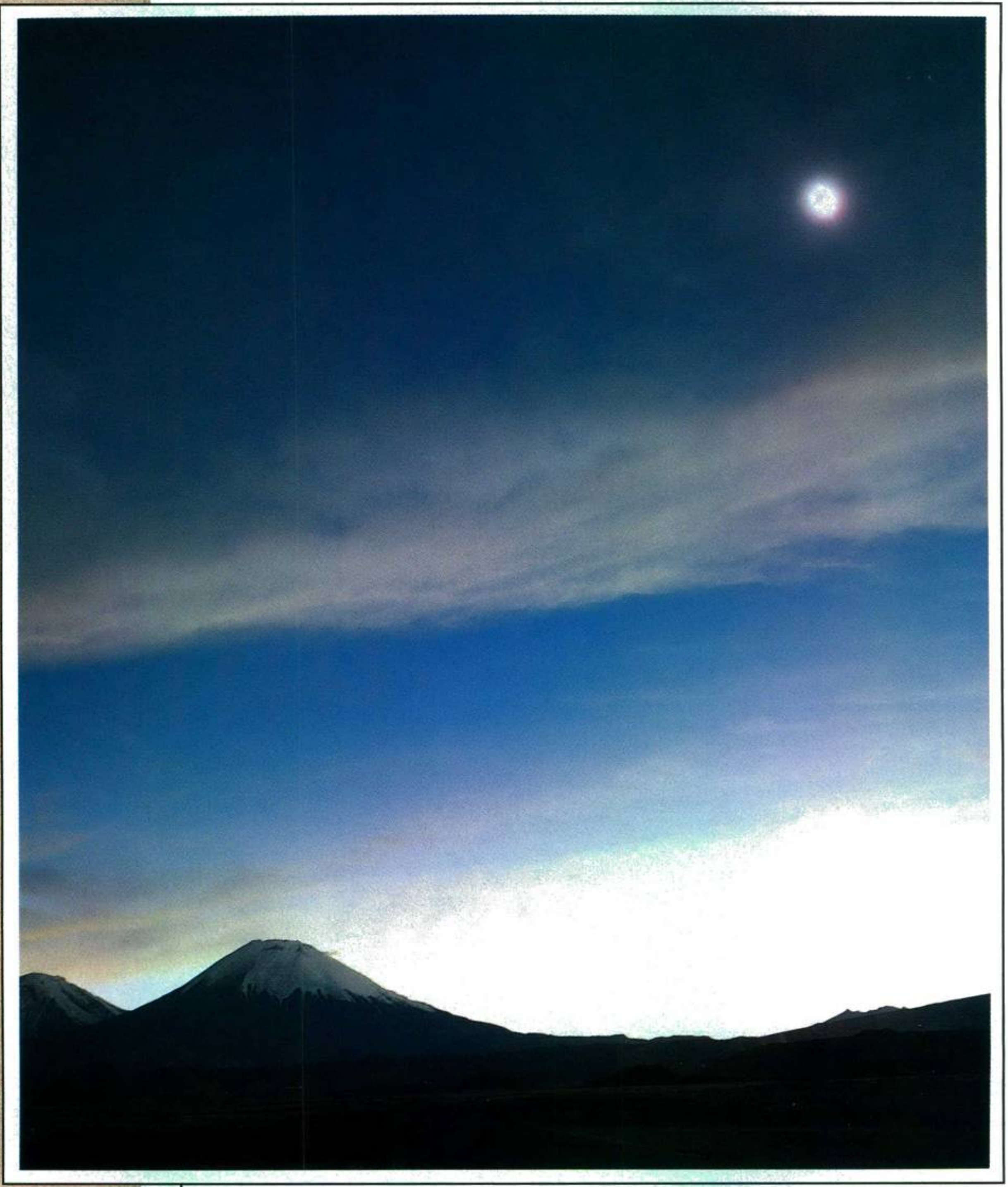


Eclipse over Lauca National Park, Chile

by Alan Dyer
(80mm lens at f/2.8, Fuji Velvia 50 film, 2 1/4-second exposure taken November 3, 1994)

"Our site at 15,200 feet provided a beautiful vista of 20,000-foot symmetrical volcanic cones on the horizon," says Dyer. "These star cinder cones, the Parinacota volcanos, were wrapped in early morning fog as we arrived. What a place for an eclipse!

"We saw nearly three minutes of totality. In the image, taken during totality, Venus is visible just to the upper right of the eclipsed Sun."

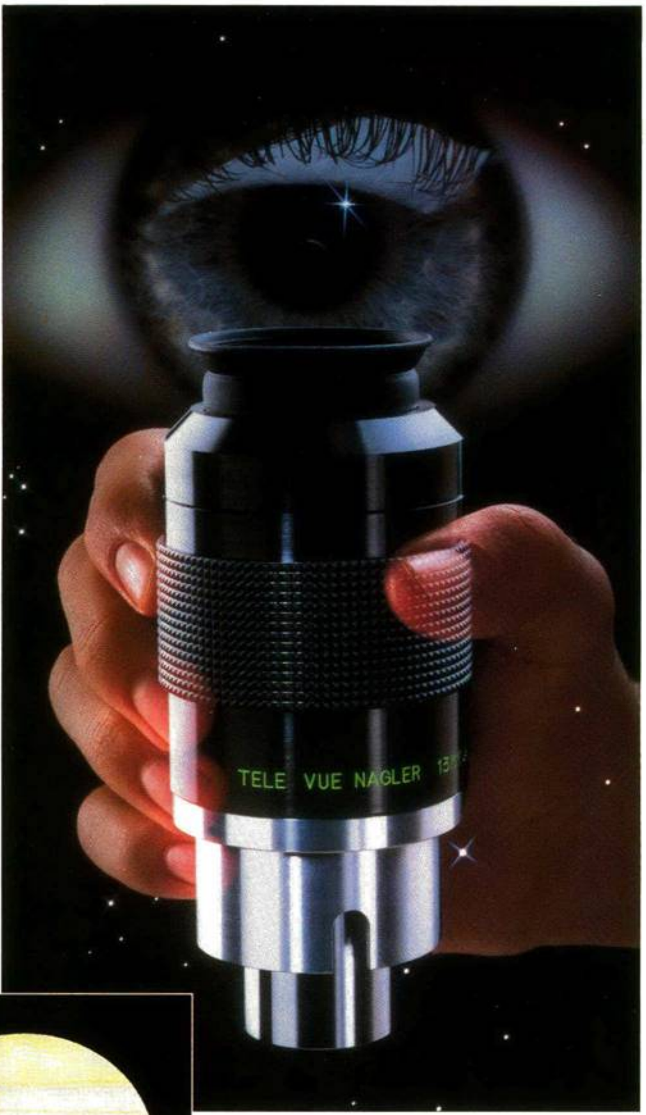
"NO OTHER EYEPIECES...SATISFY ME NOW."

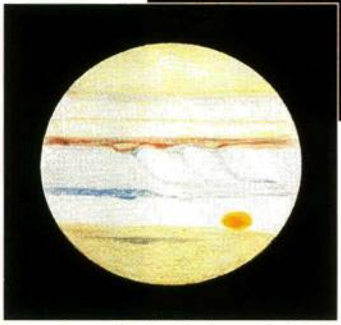
— The following unsolicited letter from a fellow enthusiast is dated Mar. 30, 1994. It is printed unedited and with permission.

Dear Mr. Nagler,

"I thought it long overdue that I write to give my impressions of your Nagler eyepiece designs. *I say 'long overdue,' because I bought my first Nagler (a 7mm) back in 1984. The reason for the purchase was that earlier that year I had invested in a Celestron C-11 and a 4" Fluorite, F/9 refractor. I thought that the stated objectives of the Nagler design — long eye-relief and a wide, highly corrected field of view, would exploit the full potential of a telescope with 2,800mm focal length, and the imaging capacities of a fine refractor. I was not disappointed. Soon after came the fantastic 9mm and 11mm Naglers and then the 4.8mm for the refractor.*

These eyepieces have given me my most rewarding hours spent at the telescope. *My main interest is in the planets which I draw and give lectures on at our local school and observatory. The observation of the planets requires painstaking hours spent at the eyepiece. The Naglers suit my purposes exactly.*





Drawn by Mr. Toohey with 12 N2

When the Type 2s were introduced onto the market I could not resist them. I purchased the 16mm and 12mm models. The 20mm seemed too large, heavy and costly, so I left it alone. These were the same reasons for not buying the 13mm (apart from the fact that by then I owned a 12mm Type 2). However, earlier this year, after years of looking through other people's 13mm and 20mm Naglers, I finally decided to take the plunge myself. ***So now I own a full set of Naglers*** *(including the wonderful 11mm which despite many offers, I will not part with).*

When I remember what eyepieces for the amateur market were like before the introduction of the Naglers (like looking down a drain pipe, or 60° fields, with astigmatism and severe edge of field aberrations), ***it is clear that your designs have taken us a quantum leap forward. No other eyepieces, in the Naglers' range of focal lengths, satisfy me now.***

Many of my fellow planetary observers say that conventional field eyepieces are sufficient. In a way they are right; good Plössls, for example, produce superb images. However, I believe the extra eye-relief, the huge field of the Naglers, coupled with marvellous image correction and the impression that ***the telescope simply gets out of the way,*** *all add up to a delightful psychological difference when using the Naglers. One feels more involved, more present to what one is viewing.*

Over the years I have found that amateur astronomers can be fairly stubbourn people in somehow defending their choice of equipment. Next thing you know they upgrade what was once, in their view, the very best available. ***Only good products stand the test of time. For me, the Naglers are such a product.*** *Not only have they remained with me; I have kept buying more of them!*

To some extent, astronomy, and particularly amateur astronomy, is about emotion and the involvement of the imagination. ***I have to say that Nagler eyepieces have captured my imagination.*** *As well as giving pride of ownership, Naglers are immensely satisfying and a joy to use.*

The little instruction sheet that comes with the eyepieces says that you wish the user 'years of exciting viewing with these eyepieces, and welcome comments on your experiences with them.' So you asked for it. After a decade of superb images (many of which remain etched on my memory; most of which I have recorded on paper) I felt it timely to share my comments and to thank you for your contribution to amateur astronomy."

Yours Sincerely.
Christopher A Toohey

Christopher Toohey, Australia

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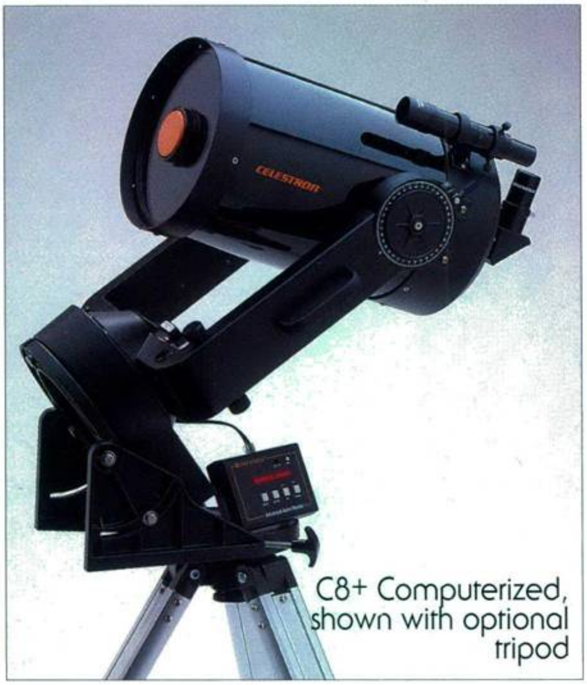
CELESTRON® C8 *Winter Bonus*



C8+ Computerized, shown with optional tripod

Ultima® 8

C8+ Telescope — For astronomy on the go, you can't beat the C8+. Runs off a single 9 volt battery for up to 50 hours. No need to be near your car or carry other 12 volt systems with cords all over the place. A hand controller is included as well as a built-in drive corrector. Starbright® coatings are standard. Optical crown glass for the corrector and a properly baffled system ensure the finest optical quality in a Schmidt-Cassegrain system. Standard accessories include: 6X30 finderscope, star diagonal – 1¼" 25mm Kellner eyepiece – 1¼" and wedge.

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